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THE MINERAL CHARACTERISTICS THAT AFFECT METAL RECOVERIES FROM THE Cu, Zn, Pb AND Ag ORES FROM MANITOBA.

PART 5.

A MINERALOGICAL EVALUATION OF THE BEHAVIOUR OF METALLIC MINERALS IN THE CHISEL LAKE CONCENTRATOR CIRCUIT.

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ABSTRACT

Samples of the feed, concentrates and tailings from the Chisel Lake concentrator circuit were taken on April 18th 1989. The samples were assayed for 8 elements, and image analysis was done to determine the modal quantities, host particle size distributions, liberations and associations of the minerals. Material balances were done to simulate the behaviour, and to determine the recovery of metals, minerals, and of free and unliberated grains of the valuable minerals in the end products.

The feed assayed 16.7 % Zn, 0.35 % Cu, 2.52 ppm Au, 38.1 ppm Ag and 0.71 % Pb. Although 95.0 % of the Zn is recovered in the Zn-concentrate, and 70.5 % of the Pb is recovered in the Pb-concentrate, only 42.6 % of the Cu, 16.3 % of the Au and 22.0 % of the Ag are recovered in the Cu-concentrate. The feed contained (in vol%) 31.8 % gangue, 37.8 % pyrite, 27.1 % sphalerite, 0.95 % pyrrhotite, 0.91 % chalcopyrite, 0.57 % galena and 0.29 % arsenopyrite. Trace amounts of tetrahedrite, stannite, cassiterite, pyrargyrite, electrum, molybdenite and native bismuth were also observed.

Of the chalcopyrite in the feed, only 54.4 % occurs as 'recoverable' grains, of which 71 % are recovered in the Cu-concentrate. A further 10.8 and 35.0 % of the chalcopyrite in the feed occur as middling and sub-middling grains, respectively. Only 25.3 % of the middling and 4.19 % of the sub-middling grains are recovered in the Cu-concentrate; 54.0 % and 66.3 %, respectively are recovered in the Zn-concentrate. The principal fractions of chalcopyrite unrecovered to the Cu-concentrate are: (1) 'recoverable' grains recovered in the Zn-concentrate; (2) middling grains recovered in the Zn-concentrate; (3) sub-middling grains recovered in the Zn-concentrate; and (4) sub-middling grains rejected to the tailings. These fractions account for 13.5, 5.9, 23.5 and 9.7 %, respectively of the Cu in the feed. The latter three fractions are liberation dependent, and are amenable to fine regrinding.

Of the sphalerite in the feed, 95.4 % occurs as 'recoverable' grains, of which 97.7 % are recovered in the Zn-concentrate, with 1.1 % rejected to the tailings. The latter fraction of 'recoverable' grains, the bulk of which are 'over-sized', account for 35 % of the sphalerite in the tailings. A further 3.51 % of the sphalerite in the feed occur as middling grains, of which 59.9 % are recovered in the Zn-concentrate, but 33.0 % are rejected to the tailings. The latter loss accounts for 1.2 % of the sphalerite in the feed, and 39 % of the sphalerite in the tailings. Sub-middling grains comprise the remaining 1.06 % of the sphalerite in the feed, of which only 15.9 % are recovered in the Zn-concentrate. The loss of 75.3 % of the sub-middling grains to the tailings accounts for only 0.84 % of the sphalerite in the feed, and 27 % of the sphalerite in the tailings.

Of the galena in the feed, 77.8 % occurs as 'recoverable' grains, of which approximately 80.7 % are recovered in the Pb-concentrate, The largest fraction of 'recoverable' grains unrecovered to the Pb-concentrate are those recovered in the Zn-concentrate (i.e. 14.1 %), and account for 11.0 % of the galena in the feed, and 70 % of the galena in the Zn-

concentrate. A further 9.41 % of the galena in the feed occurs as middling grains, of which 39.6 % are recovered in the Pb-concentrate, 15.3 % in the Zn-concentrate, but 42.1 % are rejected to the tailings. The latter loss accounts for 3.86 % of the galena in the feed, and 29 % of the galena in the tailings. Sub-middling grains comprise the remaining 12.9 % of the galena in the feed, of which only 30.8 % are recovered in the Pb-concentrate. The loss of 60.4 % of the sub-middling grains to the tailings accounts for only 7.58 % of the galena in the feed, and 57 % of the galena in the tailings.

Thus, approximately 40 % of the chalcopyrite, 2.5 % of the sphalerite and 13 % of the galena in the feed are unrecovered to the respective concentrates, and occur as either (1) middling and sub-middling grains, or to a lesser extent (2) as 'recoverable', largely 'over-sized' grains. These grains are amenable to regrinding or a finer primary grind. However, because of the exceptionally high recovery of sphalerite to the high grade Zn-concentrate, remedial actions may not be justified by the Zn, Cu and Pb losses.

The principal mineralogical controls affecting the distribution of Au and Ag were not determined. Despite the high head grade of 2.52 ppm Au, only one grain of electrum was observed, suggesting a significant 'invisible' Au content. Abundant tetrahedrite was observed, particularly in the Cu-concentrate. It is inferred that tetrahedrite, sphalerite, galena, pyrite and chalcopyrite are the principal Ag-carriers in the ore.

INTRODUCTION

A mineralogical study was conducted on mill products (i.e. concentrator slurry samples) from the Chisel Lake concentrator circuit as part of a project within the CANADA-MANITOBA MINERAL DEVELOPMENT AGREEMENT. This project entitled "The mineralogical characteristics that affect metal recoveries from the Cu, Zn, Pb and Ag ores from Manitoba" was conducted as a contract to Hudson Bay Mining and Smelting Co. Ltd. (HBM&S) from CANMET, Dept. of Energy, Mines and Resources, under the supervision of the CANMET Scientific Authority Dr. W. Petruk. The work was performed by the author at the University of Manitoba as an employee of HBM&S under this contract.

The objective of the project was to establish whether the volcanogenic massive sulphide deposits of Manitoba contain unique mineralogical characteritics, and to determine whether these characteristics can be utilized to modify metallurgical practises, so that recovery could be optimised. Mineralogical studies on the ores from the Trout Lake deposit, and mill products from the Trout Lake concentrator circuit in Flin Flon comprised Parts 1 and 2 of the project. Part 1 sought to define the mineralogical characteristics that could have a bearing on mining and mineral processing (Healy & Petruk 1988), whereas Part 2 evaluated the behaviour of the minerals in the concentrator circuit (Healy & Petruk 1989a). Part 3 evaluated the behaviour of minerals in the HBMS concentrator circuit (Healy & Petruk 1989b). Part 4 evaluated the behaviour of minerals in the Stall Lake concentrator circuit (Healy & Petruk 1990).

Part 5 of the project involved sampling the feed, concentrates and tailings of the Chisel Lake concentrator circuit, which is housed in the HBM&S Snow Lake concentrator. Sieve size, chemical, petrographic and image analysis was done on each of the four products. The image analysis included modal, grain size, mineral liberation and mineral association analysis. Material balance calculations were done on several of these analytical data, to determine the behaviour and inter-relationships of the metals and minerals through the circuit.

METHODS OF INVESTIGATION

SAMPLING

Sampling was done by HBM&S staff at Snow Lake on April 18th 1989, and submitted to the author after splits were sieved and chemically analyzed. Flotation problems in the Pb-circuit at the time of the sampling campaign, resulted in an abnormally low grade Pb-concentrate.

CHEMICAL ANALYSIS

The five samples were analysed chemically for Cu, Zn, Au, Ag, Cd, Pb, Fe, S and Sb at the HBM&S assay laboratory, Flin Flon., The dried samples required no preparation for chemical analysis, as they are fine-grained and homogeneous. The HBM&S assay laboratory have previously achieved a relatively high degree of accuracy and precision (Healy & Petruk 1988, 1989a), hence no reference ore standards were included with this batch of samples.

SIEVE SIZE ANALYSIS

The five samples were submitted to HBM&S for sieve size analysis. The samples were machine sieved, using stacked Tyler Series meshes with the mesh numbers 48, 65, 100, 150, 200 and 325. The weight of retained material in each sieve, and that passing 325 mesh was determined and recorded for each sample. The feed was ground to 48.5 % - 325 mesh.

PETROGRAPHIC AND IMAGE ANALYSIS

The five samples were prepared as polished sections at CANMET, Ottawa. Approximately 200 mg of the sample was mounted in epoxy/araldite in such a manner as to minimize fractionation of the sample by gravity settling of the particles. The polished sections were petrographically examined in preparation for image analysis. During petrographic and image analysis of the polished sections, fifteen ore minerals[1] were observed, and confirmed by EDA (See Table 4). The petrographic examination qualitatively determined the abundance, median grain size, degree of liberation, and the type of locked species of the minerals of interest. This information was useful in constructing an appropriate image analysis routine.

The image analysis was done at CANMET, Ottawa on the MP-SEM-IPS image analysis system, which was developed by Petruk (Petruk 1987). The SEM capabilities of the Jeol 733 electron microprobe, the image producing

[1] Ore minerals are informally defined here as minerals characteristic of the ore zone, but are not necessarily of economic value e.g. sulfides, alloys, sulfosalts, selenides, tellurides, etc.

component of the system, permit the generation of high resolution backscattered electron (BSE) images of the polished sample surface. The BSE (or grey level) image of a single field of the sample surface is tranferred to the Kontron SEM-IPS image analyser and digitized. Those areas of the image detected within the grey level window of each mineral are transformed into separate binary images. These mineral-specific binary images are stored in the image memory assigned to each mineral or mineral group (i.e. gangue[2] or pyrite + marcasite). At this point the various stereological measurements are made, and the procedure is repeated for successive fields. For further details of the specific technique used, see Healy & Petruk (1987, 1988, 1989a) and Petruk (1988a, 1988b).

The mineral quantitites were determined by measuring the relative areal fraction of each mineral (or group), and these were normalized to area % or volume %. Grains of the mineral(s) of interest were also described on the basis of their host particle size distribution, degree of liberation (i.e. classification) and degree of association with other minerals in composite particles. Due to a technical oversight when formulating the image analysis routine, the host particle diameter, and not the consitituent grain diameter was determined. However, the host particle and grain size are essentially equivalent for free and sub-free grains (See below), which are the dominant liberation categories of at least sphalerite and galena in the Chisel Lake circuit products. The host particle sizes of chalcopyrite, sphalerite, galena and pyrite were determined by measuring the surface areas of the host particles of the respective minerals, and using the square root of the area as the diameter. This 'equivalent square diameter' (or 'equivalent edge length of a square') gives sizes that compare closely with sieve size analyses (Petruk 1978).

The degree of liberation is measured using a classification, which describes the degree to which each particle containing a grain of the mineral of interest is locked with other minerals. The grains are classified into a four-fold classification based on the grains contribution in terms of volume % to the total volume of the particle, and hence the expected flotation characteristics of the particle. The 'free' grains are defined as comprising 99.9 to 100 % of the particle. The 'sub-free' particles are those in which the grain comprises between 99.9 % and 70 % of the particle, and which is expected to behave essentially as if free, i.e. in accordance with the flotation characteristics of the mineral of interest. The 'middling' particles are those in which the grain comprises 69.9 % to 30 % of the particle, and whose flotation characteristics are likely to mimic that of either the mineral of interest or the accompanying mineral(s). The 'sub-middling' particles are those in which the grain comprises less than 29.9 % of the particle, and whose flotation characteristics are expected to correspond to that of the dominant accompanying mineral(s).

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[2] Gangue is informally defined here as non-sulfide minerals characteristic of the surrounding hostrocks, and of no economic value i.e. silicates, carbonates and phosphates.

The mineral associations of the mineral(s) of interest were determined by measuring the relative surface area of the mineral of interest (e.g. chalcopyrite) that is in contact with another specified mineral (e.g. sphalerite). The associations are further classified on the basis of whether the mineral of interest occurs in the host particle along with just the other specified mineral (i.e. binary), or with the specified mineral and others (i.e. ternary).

Image analysis of the polished sections for each product was done using program PRGM #529, which uses a magnification of x150 (pixel size = 1.012 um) over an analytical area of approximately 40 to 120 fields per sample. The following parameters were determined (1) quantities of each mineral (or mineral group); (2) host particle size distributions and liberations (i.e. classification) of chalcopyrite, sphalerite, pyrite and galena; and (3) mineral associations of chalcopyrite, sphalerite and galena occurring in binary and ternary particles. No stereological corrections were applied to the data.

MATERIAL BALANCE CALCULATIONS

In order to evaluate plant performance and accurately describe the steady-state operation of an ore processing circuit using quantitative measurements of selected process variables (e.g. chemical assays, or mineral liberations) from different streams in the circuit, it is necessary to do material balance calculations (Laguitton & Wilson 1979). The weight of the products are unknown, and the raw analytical data contains sampling, sample preparation and analytical errors. Thus, material balance calculations are used to generate a new set of coherent data. The material balance calculations of this study were done using the MATBAL program, which uses a 'least squares refinement' technique to itteratively adjust the raw data, and produces 'best fit' or 'balanced' values (Laguitton 1985).

The product weights or stream flow rates were determined with the MATBAL program using the chemical assays of Cu, Zn, Fe, S and Pb as the most precise process variables available. Only minor adjustments in other variables were generated when material balance simulation of these process variables were based on these initial flow rates. Cross-balancing errors were also minor, indicating that the data are relatively globally coherent for different process variables. The accepted flow rates are 0.780, 1.852, 29.45 and 67.92 for the Cu-concentrate, Pb-concentrate, Zn-concentrate and tailings, respectively.

Having determined the stream flow rates for each product, these were then fixed, and other process variables were balanced by MATBAL to give adjusted values of these variables. The MATBAL program simultaneously calculated the recoveries of each variable in each product. Material balances were done on several types of data in order to determine the recoveries of metals, minerals, specific categories of free and/or unliberated grains, and of particles with specific associations of mineral pairs or ternary combinations. These data types are: (1) chemical assays;

(2) modal quantities data for all minerals of interest; (3) modal data for free chalcopyrite, sphalerite, galena and pyrite; (4) modal data for categories of free plus unliberated chalcopyrite, sphalerite, galena and pyrite; and (5) mineral association data for chalcopyrite, sphalerite and galena.

Both the chemical assay and modal quantities data were material balanced by entering the raw data directly into the MATBAL program. However, the mineral liberation and association data can only be material balanced after it is weighted in terms of the amount of the mineral(s) of interest present in each product. This is achieved by determining the modal fractions of the Cu, Zn and Pb assay in each product that occur in the specific liberation categories of the corresponding mineral to be material balanced (i.e. free, unliberated, sub-free, middling and sub-middling). This is based on the assumption that the Cu, Zn and Pb assays are more precise modal equivalent of the chalcopyrite, sphalerite and galena abundances. Importantly, because of the large number of Fe-bearing minerals, this relationship is not true of pyrite and Fe, such that the liberation data for pyrite is weighted in terms of the pyrite modal quantities.

For example, the modal fraction of the Cu assay, but not of chalcopyrite, occurring as free grains of chalcopyrite in each product were material balanced. The % liberation (i.e. % free) is the percent of the adjusted Cu assay accounted for by the adjusted modal fraction of the Cu assay that occurs as free chalcopyrite for a given product. Thus, a set of adjusted liberations are not generated by MATBAL, but are extracted from two sets of internally, but not necessarily globally, coherent data. Importantly MATBAL balances each set of process variables independently, such that the adjusted data may not cross-balance. However, ideally the closer the true values are approached for each variable, the closer the cross-balance achieved.

CHEMICAL ANALYSIS

The five samples were chemically analysed for 9 elements, and the assays are presented in Table 1. The samples are ordered for presentation starting with the feed, the Cu-concentrate, Pb-concentrate, Zn-concentrate, and the tailings. This format will be consistently used throughout the report.

Three analyses for Sb were below the detection limits of 0.01 wt%, and thus the Sb data are not considered further. The remaining 8 elements gave concentrations for all samples above their respective detection limits. The assays were adjusted by material balance calculations in order to model the steady-state operation of the circuit in terms of the assays. The adjusted assays and the calculated weights of each product are presented in Table 2. The recovery of the 8 elements in each of the end products was calculated simultaneously from these adjusted assays and are presented in Table 3.

The low Cu head grade and resulting low product weight of the Cu-concentrate, the high Zn head grade and resulting high product weight of the Zn-concentrate, and the high Pb head grade and the resulting Pb-circuit and Pb-concentrate render comparison of circuit performance with that of the Trout Lake or HBMS circuits inappropriate. Circuit performance is evaluated by comparison with that of the Heath Steele circuit of Brunswick Mining & Smelting Co. Ltd. (BMS), which produce a small bulk Cu-Pb concentrate (Chen & Petruk 1980). However, the Heath Steel head grades are typically higher in Cu, Pb and Ag, and lower in Zn and Au than those of this study.

The Chisel Lake ore has traditionally been processed in a separate circuit from Stall Lake ore, because of conflicting metallurgy i.e. Stall Lake ore is high Cu, low Zn, and Chisel Lake ore is high Zn, low Cu. The adjusted head grades of this study are 16.7 % Zn, 0.35 % Cu, 2.52 ppm Au and 38.1 ppm Ag, which are in strong contrast to the 1985 budgeted grades for Chisel Lake ore of 7.35 % Zn, 0.40 % Cu, 1.96 ppm Au and 36.7 ppm Ag (Barlin 1986). Thus, the head grades of this study are anomalously Zn- and Au-rich, and this probably contributed to some of the metallurgical problems identified in this study.

The Cu-concentrate, which has a product weight of 0.780, grades 19.1 % Cu, 13.9 % Zn and 1072 ppm Ag. The Cu grade lies narrowly outside the 'normal' range of grades (i.e. 20 to 28 % Cu), constituting 55 % of the ideal maximum obtainable grade of 34.5 % Cu, and a high enrichment ratio of 54.6. The Ag grade reflects the high ratio of concentration of the Cu-concentrate, and a Ag enrichment ratio of 28.1. Nontheless, the Ag recovery in the Cu-concentrate is only 22.0 %. The 13.9 % Zn grade, though exceptionally high by comparison to other processing circuits in the Flin Flon-Snow Lake camp, represents only a very minor loss of Zn to the Cu-concentrate. However, by comparison with the Heath Steele Cu-concentrate the Chisel Cu-concentrate is extremely Zn-rich (i.e. 13.9 Vs. 5.99 % Zn).

The Pb-concentrate, which has a product weight of 1.852, grades 27.0 % Pb, 10.4 % Zn, 0.28 % Cu and 511 ppm Ag. The Heath Steele Pb-

TABLE 1

RAW ASSAYS FOR THE FIVE CHISEL LAKE CIRCUIT END PRODUCTS.

PRODUCT	Au (ppm)	Ag (ppm)	Cu (wt%)	Zn (wt%)	Fe (wt%)	S (wt%)	Pb (wt%)	Cd (wt%)	Sb (wt%)
Feed	2.37	43.9	0.35	16.7	19.9	27.1	0.71	0.033	nd.
Cu-Conc.	53.2	1047.	19.1	13.9	24.0	32.3	2.60	0.029	0.04
Pb-Conc.	6.86	496.	0.28	10.4	24.5	35.1	27.0	0.022	0.04
Zn-Conc.	3.77	43.6	0.51	54.0	10.0	33.3	0.32	0.104	nd.
Tails.	1.37	9.95	0.07	0.78	24.7	25.5	0.14	0.002	nd.

TABLE 2

ADJUSTED ASSAYS FOR THE FIVE CHISEL LAKE CIRCUIT END PRODUCTS.

PRODUCT	PRODUCT WEIGHT.	Au (ppm)	Ag (ppm)	Cu (wt%)	Zn (wt%)	Fe (wt%)	S (wt%)	Pb (wt%)	Cd (wt%)
Feed	100.0	2.52	38.1	0.35	16.7	20.2	27.7	0.71	0.033
Cu-Conc.	0.780	52.5	1072.	19.1	13.9	24.0	32.3	2.60	0.029
Pb-Conc.	1.852	6.84	511.	0.28	10.4	24.5	35.1	27.0	0.022
Zn-Conc.	29.45	3.66	45.3	0.51	53.9	9.98	33.0	0.32	0.105
Tails.	67.92	1.34	10.2	0.07	0.78	24.4	25.1	0.14	0.002

concentrate grades 28.9 % Pb, 3.89 % Zn, 3.54 % Cu and 900 ppm Ag (Chen & Petruk 1980). Though low grade, the Pb-concentrate nonetheless recovers 70.5 % of the Pb, and with an Pb enrichment ratio of 38.0.

The Zn-concentrate, which has a product weight of 29.45, grades 53.9 % Zn and 0.51 % Cu. The Zn grade constitutes 95 % of the ideal maximum obtainable grade of 56.9 % Zn (based on the Zn-content of Chisel Lake sphalerite; See Wiggins & Craig 1980), and an enrichment ratio of only 3.2. The 0.51 % Cu grade of the Zn-concentrate is comparable to that of Heath Steele (i.e. 0.47 % Cu), but is low compared to that of the Trout Lake Zn-concentrate (i.e. 1.67 % Cu; See Healy & Petruk 1989a) and Stall Lake Zn-concentrate (i.e. 0.81 % Cu; See Healy & Petruk 1990). This low Cu grade nonetheless translates into a major loss of Cu to the Zn-concentrate (i.e. 42.9 %).

TABLE 3

ELEMENT RECOVERIES IN THE FIVE CHISEL LAKE CIRCUIT END PRODUCTS.

PRODUCT	PRODUCT WEIGHT.	Au (ppm)	Ag (ppm)	Cu (wt%)	Zn (wt%)	Fe (wt%)	S (wt%)	Pb (wt%)	Cd (wt%)
Feed	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	0.780	16.3	22.0	42.6	0.65	0.93	0.91	2.86	0.69
Pb-Conc.	1.852	5.02	24.9	1.48	1.15	2.25	2.35	70.5	1.24
Zn-Conc.	29.45	42.7	35.0	42.9	95.0	14.6	35.1	13.3	93.9
Tails.	67.92	36.0	18.1	13.0	3.17	82.3	61.6	13.4	4.14

The tailings, which has a product weight of 67.92, grades 0.78 % Zn, 0.07 % Cu, 10.2 ppm Ag and 1.34 ppm Au. With the exception of that of Cu, each of these grades are relatively high, though the losses are within the 'normal' range routinely experienced in the processing of Flin Flon-Snow Lake ores, and significantly less than those for the Heath Steele tailings (Chen & Petruk 1980).

The elements are divided into five groups on the basis of their distribution in the five end products (Table 3).

Group 1 consists of Cu and Au, which exhibit high recoveries in the Zn-concentrate (i.e. approx. 42.5 %), with moderate to high recoveries in the Cu-concentrate and tailings (i.e. < 36 %), and with minor recoveries in the Pb-concentrate (i.e. ≤ 5 %). The recovery of Cu to the Cu-concentrate is 42.6 %, with significant losses to the Zn-concentrate (i.e. 42.9 %) and tailings (i.e. 13.0 %). These losses of Cu to the Zn-concentrate and tailings suggests some potential for improved recovery. Although the losses of 36.0 % of the Au to the tailings are relatively 'normal' for Flin Flon-Snow Lake ores, recoveries of 16.3 % of the Au in the Cu-concentrate is low, whereas the loss of 42.7 % to the Zn-concentrate is high. The poor Cu and Au metallurgy of the circuit suggests that the Cu-circuit is not 'pulling hard', reflecting a strategy of not compromising the Zn metallurgy for the less important Cu metallurgy.

Group 2 consists of Ag only, which exhibits relatively uniform distribution with moderate recoveries (i.e. > 18 % and < 35 %) in all the end products. The loss of 18.1 % of the Ag to the tailings is relatively low compared to the Trout Lake (Healy & Petruk 1989a), HBMS (Healy & Petruk 1989b), and Heath Steele (Chen & Petruk 1980) concentrator circuits. However, the recovery of 35.0 % of the Ag in the Zn-concentrate is high, and probably largely reflects trace Ag in solid solution in sphalerite and chalcopyrite. The recovery of 22.0 % in the Cu-concentrate and 24.9 % in the Pb-concentrate, due to trace Ag in solid solution in

chalcopyrite and galena, and Ag in tetrahedrite and electrum, shows that only 46.9 % of the Ag is recovered into products from which it can be directly gained during smelting.

Group 3 consists of Zn and Cd, which exhibit exceptionally high recoveries (i.e. 95.0 and 93.9 %, respectively) to the Zn-concentrate. By comparison with Zn losses to other Flin Flon-Snow Lake Cu-concentrates (i.e. approx. 15 %), the loss of only 0.65 % of the Zn to the Cu-concentrate is negligible. Similarly, the losses of only 1.15 and 3.17 % of the Zn to the Pb-concentrate and tailings, respectively are low, and indicate minimal lattitude for improved Zn recovery.

Group 4 consists of Pb only, which is the only element to exhibit relatively high recoveries (i.e. 70.5 %) to the Pb-concentrate, with low to moderate recoveries in the Cu-concentrate (i.e. 2.86 %), Zn-concentrate (i.e. 13.3 %) and tailings (i.e. 13.4 %). The recovery of 70.5 % of the Pb in the Pb-concentrate is high by comparison with that of the Heath Steele circuit (i.e. 49.9 %), particularly as the Pb head grade is low (i.e. 0.71 % Pb) compared to the Heath Steele head grade (i.e. 1.64 %; See Chen & Petruk 1980). Although, only 2.86 % of the Pb is recovered in the Cu-concentrate, the enrichment ratio for Pb in Cu-concentrate is 3.7, yet less than unity for Pb in the Zn-concentrate and tailings.

Group 5 consists of Fe and S, which exhibit relatively high rejection to the tailings (i.e. 61.6 and 82.3 %, respectively), moderate recoveries to the Zn-concentrate (i.e. 14.6 and 35.1 %, respectively), and minor recoveries to the Cu- and Pb-concentrates (i.e. < 2.35 %). These distributions reflect the essentially inert flotation behaviour of the principal host minerals pyrite, pyrrhotite, Fe-bearing silicate gangue, but also the significant contribution from those fractions of the Fe and particularly S assays that occur in sphalerite.

By comparison with BMS's Heath Steele circuit, Chisel Lake circuit performance is generally superior. The Chisel Lake feed contains lower Cu (i.e. 0.35 Vs 1.25 %), Pb (i.e. 0.71 Vs 1.64 %) and Ag (i.e. 38.1 Vs 90 %), but higher Zn (i.e. 16.7 Vs 4.34 %) grades than the Heath Steele feed. Nonetheless, the losses of Zn, Cu, Pb and Ag to the Chisel Lake tailings are significantly lower than those to the Heath Steele tailings (Chen & Petruk 1980). The recovery of Zn (i.e. 95.0 %) and Pb (i.e. 70.5 %) to the Zn- and Pb-concentrates, respectively far exceeed those to the corresponding Heath Steele concentrates (i.e. 74.1 and 49.9 %, respectively). However, the recovery of Cu to the Cu-concentrate (i.e. 42.6 %) is less than to the Heath Steele Cu-concentrate (i.e. 53.0 %). HBM&S presently recover the Cu from the Zn-concentrate during processing at the Flin Flon Zn-plant, whereas BMS are not paid for Cu in the Heath Steele Zn-concentrate. Althlough, Ag losses to the tailings (i.e. 18.1 %) are lower than those to the Heath Steele tailings (i.e. 38.6 %), the Ag recovered in the Cu- and Pb-concentrates (i.e. 22.0 and 24.9 %, respectively) is lower than that in the corresponding Heath Steele concentrates (i.e. 24.3 and 28.0 %, respectively). However, BMS are not paid for the Ag recovered secondarily from the Zn-concentrate. Because of the higher recovery of Ag in the Zn-concentrate (i.e. 35.0 %) compared to the Heath Steele Zn-concentrate (i.e. 9.24 %), which HBM&S largely recover during Zn-refining, the Chisel Lake Ag-metallurgy is superior.

MINERAL QUANTITIES ANALYSIS AND MINERAL BALANCES

This section describes the evaluation of the modal quantities of the principal ore minerals (See Table 4) in the five end products. Mineral quantities were determined by image analysis system as described in the PETROGRAPHIC AND IMAGE ANALYSIS. This involved measuring the relative areal fraction of minerals within the polished section. The data are presented in the stereologically equivalent units of volume %.

The mineral quantities of gangue, pyrite, pyrrhotite, chalcopyrite, sphalerite, arsenopyrite and galena were determined. Minor marcasite and magnetite contribute to the pyrite mineral quantities. Determination of the modal quantities of the trace minerals tetrahedrite (See Plate 1A), pyrargyrite (See Plate 1B), stannite (See Plate 1C), cassiterite (See Plate 1D), electrum (See Plate 1E), molybdenite (See Plate 1F) and native bismuth (See Plate 1G) were not undertaken.

MATERIAL BALANCES OF THE MINERAL QUANTITIES

The raw modal analyses for the five end product are presented in Table 5. and these were adjusted by material balance calculations in order to simulate their behaviour through the circuit under the steady state conditions. The adjusted mineral quantities are given in Table 6, while the calculated recoveries are given in Table 7. It is apparent by comparing Tables 5 and 6 that the adjustments to the raw data are relatively minor for all minerals. Also shown in Table 6, under the column entitled 'Total' is the sum of these adjusted mineral quantities for each product. It is apparent that there is a minor cross-balancing deficit in all products. The magnitude of this systematic error (i.e. ≤ 3 %) is within acceptable limits.

The calculated Cu assays derived from the adjusted mineral quantities of chalcopyrite are 0.33 % Cu in the feed, 18.1 % Cu in the Cu-concentrate, 0.16 % Cu in the Pb-concentrate, 0.49 % Cu in the Zn-concentrate, and 0.06 % Cu in the tailings. These compare favourably with the adjusted Cu assays of 0.35 % Cu, 19.1 % Cu, 0.28 % Cu, 0.51 % Cu, and 0.21 % Cu in the respective products. The calculated Zn assays derived from the adjusted mineral quantities of sphalerite are 15.4 % Zn in the feed, 12.6 % Zn in the Cu-concentrate, 5.52 % Zn in the Pb-concentrate, 49.6 % Zn in the Zn-concentrate, and 0.32 % Zn in the tailings. These compare only satisfactorily with the adjusted Zn assays of 16.7 % Zn, 13.9 % Zn, 10.4 % Zn, 53.9 % Zn, and 0.78 % Zn in the respective products. The calculated Pb assays derived from the adjusted mineral quantities of galena are 0.90 % Pb in the feed, 2.28 % Pb in the Cu-concentrate, 27.9 % Pb in the Pb-concentrate, 0.45 % Pb in the Zn-concentrate and 0.11 % Pb in the tailings. These compare favourably with the adjusted Pb assays of 0.71 % Pb, 2.60 % Pb, 27.0 % Pb, 0.32 % Pb and 0.14 % Pb in the respective products. Thus, with the possible exception of Zn, the data indicates reasonably good agreement between the chemical and mineral quantities analyses.

TABLE 4

ORE MINERALS OBSERVED IN THE CHISEL LAKE END PRODUCTS.

NAME	FORMULA	ABUNDANCE
SULFIDES.		
Pyrite	FeS_2	Major.
Chalcopyrite	$CuFeS_2$	Major/Minor.
Sphalerite	ZnS	Major.
Pyrrhotite	$Fe_{(1-x)}S$	Major.
Galena	PbS	Major/Minor.
Marcasite	FeS_2	Minor/Trace.
Molybdenite	MoS_2	Trace.
SULFARSENIDES		
Arsenopyrite	$FeAsS$	Minor/Trace.
OXIDES.		
Magnetite	Fe_3O_4	Minor.
Cassiterite	SnO_2	Trace.
SULFOSALTS.		
Tetrahedrite	$(Cu,Ag)_{10}(Fe,Zn)_2(Sb,As)_4S_{13}$	Trace.
Stannite	Cu_2FeSnS_4	Trace.
Pyrargyrite	Ag_3SbS_3	Trace.
METALS AND ALLOYS.		
Electrum	$AuAg$	Trace.
Native Bismuth	Bi	Trace.

Presented in order of decreasing abundance of the mineral groups, and of the minerals in each group.

TABLE 5

RAW MINERAL QUANTITIES OF THE MINERALS OF INTEREST IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Gangue	Pyrite	Pyrr.	Cpy. (vol%)	Sphal.	Asp.	Gal.
Feed	33.1	35.7	1.14	0.88	28.5	0.26	0.514
Cu-Conc.	12.0	11.4	0.90	51.5	22.4	0.27	1.460
Pb-Conc.	5.68	51.4	1.55	0.57	12.6	2.65	25.50
Zn-Conc.	8.18	3.50	0.81	1.87	85.3	0.03	0.290
Tails.	41.7	56.2	0.90	0.11	0.56	0.40	0.070

TABLE 6

ADJUSTED MINERAL QUANTITIES OF THE MINERALS OF INTEREST IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Gangue	Pyrite	Pyrr.	Cpy. (vol%)	Sphal.	Asp.	Gal.	Total.
Feed	31.8	37.8	0.95	0.91	27.1	0.29	0.568	99.42
Cu-Conc.	12.0	11.4	0.90	50.6	22.4	0.27	1.457	99.03
Pb-Conc.	5.68	51.3	1.56	0.57	12.6	2.59	23.03	97.33
Zn-Conc.	8.20	3.49	0.84	1.38	89.1	0.03	0.285	103.3
Tails.	43.1	52.7	0.98	0.15	0.56	0.35	0.069	97.91

The minerals can be placed in four groups on the basis of their distribution in the five end products (Table 7), and these are described below.

Group 1 consists of gangue, pyrite, pyrrhotite and arsenopyrite, all of which are principally rejected to the tailings (i.e. > 70 %), reflecting their largely inert behaviour during flotation. These minerals exhibit comparable minor recoveries to the Cu-concentrate (i.e. < 0.75 %). However, while gangue and pyrite are largely rejected to the tailings (i.e. > 91 %), significant amounts of pyrrhotite are recovered in the Zn-concentrate (i.e. 26.1 %), and arsenopyrite in the Pb-concentrate (i.e. 16.3 %). Significantly, petrographic examination shows that the bulk of the pyrrhotite in the Zn-concentrate is free and relatively coarse-

TABLE 7

RECOVERY OF THE MINERALS OF INTEREST IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Gangue	Pyrite	Pyrr.	Cpy. (%)	Sphal.	Asp.	Gal.
Feed	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	0.29	0.24	0.74	43.3	0.65	0.72	2.00
Pb-Conc.	0.33	2.48	3.03	1.14	0.85	16.3	74.9
Zn-Conc.	7.60	2.73	26.1	44.5	97.1	3.00	14.8
Tails.	91.8	94.6	70.2	11.1	1.41	80.0	8.28

grained. Also significant, is that despite the relatively low pyrite recovery to the Pb-concentrate (i.e. 2.48 %), the pyrite content of the Pb-concentrate is 51.3 %. (See Plate 1H).

Group 2 consists of chalcopyrite only, which exhibits only moderate recovery to the Cu-concentrate (i.e. 43.3%), but also to the Zn-concentrate (i.e. 44.5 %). Chalcopyrite exhibits low recovery (i.e. 1.14 %) in the Pb-concentrate, but an additional 11.1 % is rejected to the tailings. The recovery of 43.3 % of the chalcopyrite in the Cu-concentrate is significantly lower than that for the Heath Steele circuit (i.e. 53.0 %; See Chen & Petruk 1980). The significant losses of chalcopyrite to the Zn-concentrate and tailings combined (i.e. 56 %) indicate considerable lattitude for improved recovery, depending on the chalcopyrite's size and liberation characteristics.

Group 3 consists of sphalerite only, of which 97.1 % is recovered in the Zn-concentrate, with consequently only minor losses (i.e. < 1.5 %) to each of the Cu-concentrate, Pb-concentrate and tailings. The disparity between the recovery of sphalerite (i.e. 97.1 %) and Zn (i.e. 95.0 %) is not significant within the uncertainties of the image and chemical analyses. Furthermore, the Zn-spinel gahnite ($ZnAl_2O_4$), which contains approximately 33 % Zn, and which was observed in the Stall Lake circuit products (Healy & Petruk 1990), but was not sought in the Chisel Lake circuit products, may comprise a small fraction of the Zn assays. Gahnite is expected to report principally to the tailings, and thus generate a discrepancy between the losses of Zn (i.e. 3.17 %) and sphalerite (i.e. 1.41 %) to the tailings. Nonetheless, sphalerite (or Zn) recovery of this magnitude is exceptionally high, and is significantly higher than Zn recoveries reported for the Heath Steele (i.e. < 75 %; See Chen & Petruk 1980). Clearly, only minor lattitude exists for improving sphalerite recovery.

Group 4 consists of galena only, of which 74.9 % is recovered in the Pb-concentrate, and which exceeds the 49.9 % Pb recovery reported for the

Heath Steele circuit (Chen & Petruk 1980). However, the recovery of Pb in the Pb-concentrate (of this study) is only 70.5 %. This disparity largely reflects the uncertainties in the modal analysis of galena, resulting in discrepancies between the material balances of the Pb assays and galena mineral quantities. Nonetheless, these two sets of material balance data are relatively coherent. The minor loss of 2.0 % of the galena to the Cu-concentrate is in contrast to that in the Heath Steele Cu-concentrate (i.e. 8.78 %; See Chen & Petruk 1980). The principal loss of galena is to the Zn-concentrate (i.e. 14.8 %) and the tailings (i.e. 8.28 %). However, the more precise adjusted Pb assays show that the losses in the Zn-concentrate and tailings are equivalent (i.e. 13.3 and 13.4 %, respectively), and indicate potentially substantial lattitude for improved Pb recovery. In the Heath Steele circuit, the loss of Pb is substantially higher to the tailings (i.e. 37.0 %) than to the Zn-concentrate (i.e. 4.4 %; See Chen & Petruk 1980).

The losses of Zn (sphalerite), Cu (chalcopyrite), Pb (galena) and Ag (several host minerals) to the Chisel Lake tailings are significantly lower than those to the Heath Steele tailings (Chen & Petruk 1980). Furthermore, unlike BMS, HBM&S recover much of the valuable metals that are not rejected to the tailings, but which are not recovered in the appropriate concentrate. Because the losses of Cu, Zn, Pb and Ag to tailings are all lower at Chisel Lake than at Heath Steele, the Chisel Lake metallurgy is superior. However, the recovery of these metals during Cu-smelting and Zn-refining strongly influences the strategy of the circuit flotation, and thus biases the comparison of metallurgical efficiency. Because of this bias in evaluating metallurgical accounting, and because the feed ores are substantially different, Chisel Lake circuit performance can only be evaluated by examining the performance of process variables such as grain size, liberation, flotation efficiency and selective flotation of the valuable minerals.

PLATE 1

PLATE 1

(A) Cu-CONCENTRATE : A grain of free, coarse-grained, Ag-rich tetrahedrite (Tet). Tetrahedrite is most abundant in the Cu-concentrate, and occurs as free or unliberated grains, which are largely locked with galena. Chalcopyrite (Cp), pyrite (Py) and galena (Gal) comprise the principal sulfides in the field. Scale Bar = 100 um. Backscattered electron (BSE).

(B) Pb-CONCENTRATE : Composite particle consisting of pyrargyrite (Pyr) filling a fracture in pyrite. This is the only observation of pyrargyrite. Note abundant free pyrite, galena and sphalerite (Sp). Scale Bar = 10 um. BSE.

(C) Cu-CONCENTRATE : Composite particle consisting of pyrite with three fine-grained, rounded inclusions of stannite (St). Scale Bar = 10 um. BSE.

(D) TAILINGS : Coarse-grained, free cassiterite (Cst); relatively common in the tailings. Other sulfides are free pyrite and pyrrhotite (Po). Scale Bar = 100 um. BSE.

(E) Cu-CONCENTRATE : Large, sub-free mass of electrum (El) locked with pyrite and chalcopyrite. Electrum is inhomogeneous, containing a high-Au veinlet that is not visible at the low contrast of this image. Scale Bar = 10 um. BSE.

(F) TAILINGS : Fine-grained inclusion of molybdenite (Mo) in pyrite. Only this one grain was observed. Scale Bar = 10 um. BSE.

(G) TAILINGS : Coarse-grained galena containing fine veinlet of native bismuth (Bi), descernible in circled area, but anastomoses extensively throughout the grain. Scale Bar = 10 um. BSE.

(H) Pb-CONCENTRATE : Abundant medium-grained free and unliberated grains of pyrite, and lesser galena and sphalerite. Note pyrite is largely free and comprises approximately 50 % of concentrate. Note only minor gangue (Gan). Scale Bar = 100 um. BSE.

(I) Zn-CONCENTRATE : Several coarse-grained ('over-sized') free grains of chalcopyrite (at center and top left). Also note lesser medium-grained free grains (center left), and fine-grained sub-middling grains locked with sphalerite. Note only minor pyrite and trace gangue. Scale Bar = 160 um. Plane Polarised Light.

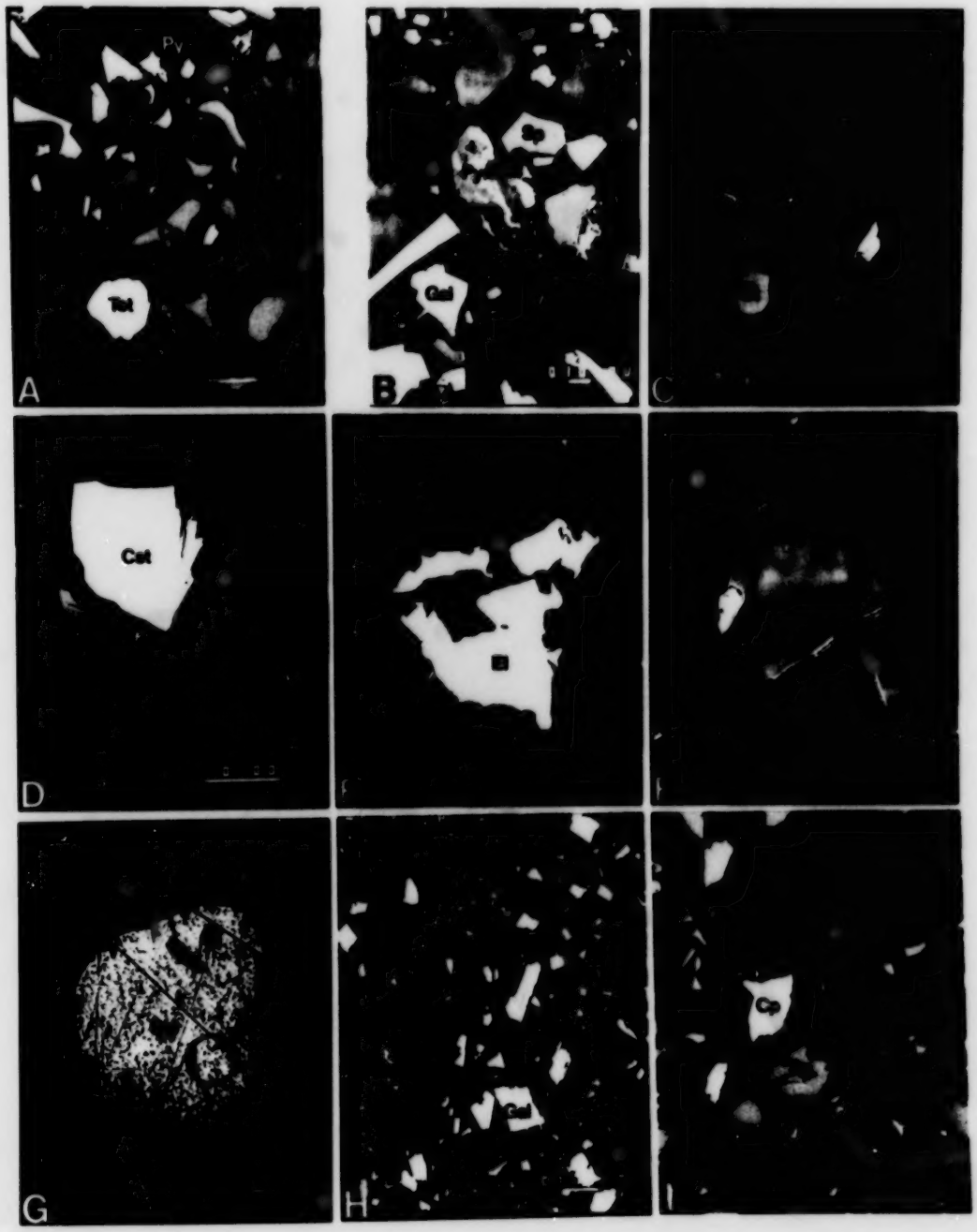
A
B
C
D
G
H
I

PLATE 2

PLATE 2

(A) Zn-CONCENTRATE : Free, coarse-grained ('over-sized') chalcopyrite (Cp) at lower left. Other free and unliberated (locked with sphalerite (Sp)), medium-grained chalcopyrite are indicated (i.e. a to c). Pyrite (Py) is the only other sulfide in the field. Scale Bar = 160 um. Plane Polarised Light (PPL).

(B) TAILINGS : 'Over-sized' particle consisting of diablastic-textured chalcopyrite and sphalerite. Note abundant coarse-grained, inclusion-free pyrite and gangue (Gan). Scale Bar = 160 um. PPL.

(C) TAILINGS : Three 'over-sized' free and sub-free grains of sphalerite. Inclusions in sphalerite consist largely of fine-grained pyrite and lesser chalcopyrite. Scale Bar = 160 um. PPL.

(D) TAILINGS : Four grains of sphalerite in field; two free, 'over-sized' grains (b and d), one fine-grained free grain (c), and one grain locked with pyrite (b). Scale Bar = 160 um. PPL.

(E) Cu-CONCENTRATE : Abundant medium-grained, free and unliberated grains of sphalerite. Bulk of unliberated sphalerite is locked with chalcopyrite (i.e. a to e), with minor sphalerite locked with pyrite. PPL. Scale Bar = 160 um.

(F) Pb-CONCENTRATE : Abundant medium-grained, free pyrite, sphalerite and galena (gal). Unliberated sphalerite principally locked with galena. Much of the galena exhibits cubic grain shapes from breakage on cleavages (i.e. a to d). Scale Bar = 160 um. PPL.

A
B
C
D
E
F
Sp
Sp

MINERAL LIBERATIONS AND ASSOCIATIONS

In this section the liberation, classification and association of chalcopyrite, sphalerite and galena, and the liberation data of pyrite in the circuit products are evaluated. The liberation (% free) is the relative volume % of each mineral of interest that occurs as free grains; the remainder, the unliberated grains occur in composite particles with one or more other minerals. Grains of the minerals of interest are classified into a four-fold classification based on their volume % of the host particle, and hence its probable behaviour during flotation (See PETROGRAPHIC AND IMAGE ANALYSIS). The raw liberation data are tabulated in appendix B, and the raw association data are tabulated in appendix C.

MATERIAL BALANCES OF MINERAL LIBERATIONS AND ASSOCIATIONS

The raw liberation, classification and association data for chalcopyrite, sphalerite and galena, and the liberation data for pyrite in each of the end product samples were transformed into coherent sets of data by material balance calculations. The liberation and classification data for chalcopyrite, sphalerite and galena were first weighted in terms of the amount of the mineral present in each product using the corresponding assays for Cu, Zn and Pb as the more precise modal equivalents of these minerals e.g. the Cu assay was multiplied by the liberation (% free) of chalcopyrite in that product. These raw modal fractions of the Cu assay were transformed by MATBAL into sets of adjusted modal fractions of the Cu assay and recoveries for the same were calculated. The adjusted modal fractions were subsequently divided by the respective Cu assay for that product, to give adjusted, but non-coherent liberations. Thus, a set of adjusted liberations is not generated, but is extracted from two sets of coherent data. This procedure was done on (1) the four-fold classification and mineral associations for chalcopyrite, sphalerite and galena (using the Cu, Zn and Pb assays, respectively), and (2) the liberation data (i.e. % free, % unliberated and % sub-free) for pyrite (using the pyrite mineral quantities).

CHALCOPYRITE

The raw modal fraction of the adjusted Cu assay occurring as free, unliberated, sub-free, middling and sub-middling chalcopyrite grains in each end product are given in Table 8. The adjusted equivalents of each of these categories are given in Table 9, whereas the corresponding recoveries of these are given in Table 10. The Cu recovery in each product was multiplied by the adjusted modal fraction of each category of chalcopyrite to give the adjusted modal fraction of the Cu recovery occurring as free, sub-free, middling and sub-middling chalcopyrite in each product. The latter data are given in Table 11, and plotted as histograms on a simplified circuit diagram in Figure 1. The first row of data in Table 11 gives the adjusted classification of chalcopyrite in the feed, which is: 21.4 % occur as free, 33.0 % as sub-free, 10.8 % as middling and 35.0 % as sub-middling grains of chalcopyrite.

Of the chalcopyrite in the feed 21.4 % occurs as free and 33.0 % as sub-free grains. Thus, only 54.4 % of the chalcopyrite occurs as free plus sub-free or 'recoverable' grains, constituting relatively low 'effective' liberation. These grains are expected to behave as free grains and hence be recovered in the Cu-concentrate. Of these, 68.9 % of the free and 72.9 % of the sub-free grains are recovered in the Cu-concentrate (See Table 10), and account for 38.5 of the 42.6 % (i.e. 90.4 %) Cu-recovery in the Cu-concentrate (See Table 11). The bulk of the remaining chalcopyrite is recovered in the Zn-concentrate (i.e. 23.9 % of the free and 25.0 % of the sub-free), with relatively high losses to the tailings (i.e. 6.69 % of the free and 0.61 % of the sub-free), and minor losses to the Pb-concentrate (i.e. 0.49 % of the free and 1.50 % of the sub-free). The high losses of 29 % of these 'recoverable' grains correspond to 15.7 % of the chalcopyrite in the feed. These losses account for approximately 32, 39 and 13 % of the chalcopyrite in the Zn-concentrate, Pb-concentrate and tailings, respectively. These losses of 'recoverable' grains correspond to 16 % of the Cu in the feed (i.e. 0.06 % Cu), and are thus relatively insignificant. Furthermore, the Cu lost to the Zn-concentrate is largely recovered during subsequent Zn-refining. Only 1.6 % of the chalcopyrite in the feed rejected to the tailings as 'recoverable' grains, accounting

TABLE 8

RAW CHALCOPYRITE LIBERATIONS IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Total Cu Assay	Free	Unliberated	Sub-free	Middling	Sub-middling
		(Modal Fraction of the Cu assay)				
Feed	0.35	0.16	0.19	0.12	0.02	0.05
Cu-Conc.	19.1	4.85	14.3	12.4	1.26	0.63
Pb-Conc.	0.28	0.02	0.26	0.09	0.09	0.08
Zn-Conc.	0.51	0.06	0.46	0.10	0.08	0.28
Tails.	0.07	0.01	0.06	0.00	0.01	0.05

for 0.01 % Cu assay in the tailings.

In addition to the 54.4 % recoverable chalcopyrite in the feed, 10.8 % occurs as middling grains and 35.0 % as sub-middling grains. The middling grains are predominantly recovered in the Zn-concentrate (i.e. 54.0 %), with 25.3 % recovered in the Cu-concentrate, 4.59 % in the Pb-concentrate, and 16.2% rejected to the tailings. The losses to the Zn-concentrate, Pb-concentrate, and tailings correspond to 5.89, 0.48 and 1.71 %, respectively of the chalcopyrite in the feed. The combined losses (to the Zn-concentrate, Pb-concentrate and tailings) of these grains correspond to 8.08 % of the chalcopyrite in feed (See Table 11). However, these lost

TABLE 9

ADJUSTED CHALCOPYRITE LIBERATIONS IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Total Cu Assay	Free	Unliberated	Sub-free	Middling	Sub-middling
		(Modal Fraction of the Cu assay)				
Feed	0.35	0.07	0.26	0.11	0.04	0.12
Cu-Conc.	19.1	6.35	12.1	10.4	1.17	0.63
Pb-Conc.	0.28	0.02	0.26	0.09	0.09	0.08
Zn-Conc.	0.51	0.06	0.39	0.09	0.07	0.27
Tails.	0.07	0.01	0.06	0.00	0.01	0.05

TABLE 10

RECOVERY OF CHALCOPYRITE LIBERATIONS IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Cu Recovery	Free	Unliberated	Sub-free	Middling	Sub-middling
		Recovery (%)				
Feed	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	42.6	68.9	37.0	72.9	25.3	4.19
Pb-Conc.	1.48	0.49	1.90	1.50	4.59	1.26
Zn-Conc.	42.9	23.9	45.5	25.0	54.0	66.3
Tails.	13.0	6.69	15.6	0.61	16.2	28.2

middling fractions only correspond to a Cu assay of 0.028 % Cu in the feed. Although middling grains are the most amenable to regrinding, only 10.8 % of the chalcopyrite in the feed occurs as middling grains, and losses of these are relatively insignificant.

The sub-middling grains comprise 35.0 % of the chalcopyrite in the feed and are predominantly recovered in the Zn-concentrate (i.e. 66.3 %), with recoveries of only 4.19 % in the Cu-concentrate. In addition, 1.26 % is recovered in the Pb-concentrate, with 28.2 % rejected to the tailings. The sub-middling grains recovered in the Zn-concentrate correspond to 23.5 % of the chalcopyrite in the feed, and account for approximately 55 % of the chalcopyrite in the Zn-concentrate. The minor loss of 1.26 % of the sub-middling grains to the Pb-concentrate corresponds to 0.42 % of the chalcopyrite in the feed. The combined loss of 96 % of the sub-middling chalcopyrite grains to the Zn-concentrate, Pb-concentrate and tailings,

corresponding to 34 % of the chalcopyrite in the feed, is the largest fraction of unrecovered chalcopyrite. These losses are only redressable by extremely fine regrinding of streams preferentially enriched in the sub-middling fraction.

The principal fractions of Cu (and hence chalcopyrite) not recovered in the Cu-concentrate are lost to the Zn-concentrate as: (1) 'recoverable' grains (i.e. 13.5 %); (2) middling grains (i.e. 5.89 %); (3) sub-middling (i.e. 23.5 %); and to the tailings as: (4) sub-middling grains (i.e. 9.71 %). These specific losses correspond to 52.6 % of the Cu in the

TABLE 11

RECOVERY OF THE Cu ASSAY IN THE FIVE CHISEL LAKE END PRODUCTS IN TERMS OF THE MODAL FRACTION OF CHALCOPYRITE OCCURRING AS FREE, SUB-FREE, MIDDLING AND SUB-MIDDLING GRAINS.

PRODUCT	Cu Recovery	Free	Sub-free	Middling	Sub-middling
		Recovery (%)			
Feed	100.0	21.4	33.0	10.8	35.0
Cu-Conc.	42.6	14.6	23.9	2.70	1.45
Pb-Conc.	1.48	0.10	0.48	0.48	0.42
Zn-Conc.	42.9	5.19	8.35	5.89	23.5
Tails.	13.0	1.41	0.20	1.71	9.71

feed, but these only account for 0.18 % Cu of the 0.35 % Cu head grade.

Although 'recoverable' grains comprise 54.4 % of the chalcopyrite in the feed, the combined loss (to the Zn- and Pb-concentrates and tailings) of 28.9 % of these (i.e. 15.7 % of the chalcopyrite in the feed) is substantially lower than the losses of 74.8 and 95.8 % of the middling and sub-middling fractions, respectively to these same products (i.e. 41.7 % of the chalcopyrite in the feed). Extremely fine regrinding of a stream enriched in the middling and particularly sub-middling fractions of chalcopyrite may increase the liberation and recovery of chalcopyrite. Regrinding would also address the losses of 'over-sized' 'recoverable' chalcopyrite (See Plate 1I, 2A and 2B), which however comprise only a relatively minor fraction of the 'recoverable' chalcopyrite recovered in the Zn-concentrate. Thus, regrinding has the potential of increasing liberation from the middling and sub-middling categories of chalcopyrite, resulting in increased Cu recovery of up to approximately 40 %. However, as these losses correspond to less than 0.15 % Cu in the feed, remedial action may not be economically justified.

The losses of 'recoverable' chalcopyrite, which are thus liberation independent, are (with the exception of the minor 'over-sized' component) not amenable to improved recovery through regrinding. These losses are largely due to poor selective flotation of chalcopyrite. However, increasing the 'pull' on the Cu-circuit, may result in substantial losses of Zn (and Pb) to the Cu-concentrate, and thus severely compromise Zn metallurgy. Furthermore, as 75 % of the lost chalcopyrite is recovered in the Zn-concentrate, and which is largely recovered by HBM&S during Zn-refining, the economic benefit of any remedial action is uncertain.

The raw mineral association data for chalcopyrite (Table 1 of appendix C) were material balance adjusted (Table 2 of appendix C) and recoveries of these were calculated (See Table 12). Also given on the first row of data in Table 12 are the modal percentages of chalcopyrite occurring in each specific association category of chalcopyrite. It is apparent from these data that the bulk of the chalcopyrite occurs in ternary particles (i.e. 57.1 %), with lesser fractions as free grains (i.e. 19.4 %), binary particles of chalcopyrite-sphalerite (i.e. 14.2 %), chalcopyrite-gangue (i.e. 7.97 %), chalcopyrite-pyrite (i.e. 0.97 %) and chalcopyrite-galena (i.e. 0.39 %). The latter two categories comprise less than 1.5 % of the chalcopyrite in the feed, are thus insignificant and are

TABLE 12

RECOVERY OF THE MINERAL ASSOCIATIONS OF CHALCOPYRITE IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Cu Recovery	Free Cpy	Cpy+Py	Cpy+Gan	Cpy+Sph	Cpy+Gal	Ternary Cpy
Feed	-----	19.4	0.97	7.97	14.2	0.39	57.1
Feed	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	42.6	68.9	78.4	70.9	7.89	36.5	42.1
Pb-Conc.	1.48	0.49	0.53	0.19	0.47	12.3	2.08
Zn-Conc.	42.9	23.9	8.61	26.5	90.3	18.9	36.0
Tailings	13.0	6.69	20.1	2.36	1.33	36.2	19.8
Tailings	-----	13.6	1.36	1.36	1.36	0.95	81.4

Note: The first and last rows of data present the adjusted modal percents of chalcopyrite occurring in specific association categories in the feed and tailings, respectively. These were calculated by dividing the Cu assay by the corresponding adjusted modal fraction of the Cu assay occurring in each category (See Table 2 of appendix C).

not considered further.

Each of the remaining four categories show only minor losses to the Pb-concentrate (i.e. < 2.1 %), which are thus essentially insignificant. Recoveries to the Cu-concentrate vary from 70.9 % for chalcopyrite-gangue, 68.9 % for free, 42.1 % for ternary and 7.89 % for chalcopyrite-sphalerite particles. Thus, the chalcopyrite-sphalerite particles exhibit the lowest recoveries to the Cu-concentrate, with 90.3 % recovered in the Zn-concentrate. This distribution seems to reflect a 'soft-pulling' Cu-circuit so as to optimize sphalerite recovery to the 'hard-pulling' Zn-circuit. However, petrographic examination indicates that chalcopyrite-sphalerite particles tend to consist largely of sub-free sphalerite with sub-middling chalcopyrite, (See Plate 1I and 2A), which would be expected to be recovered in the Zn-concentrate even under 'normal' flotation conditions. The principal losses in each of the other three categories are also to the Zn-concentrate (from 23.9 % of the free, to 36.0 % of the ternary chalcopyrite category). Consequently, ternary chalcopyrite comprises 51 %, chalcopyrite-sphalerite 32 %, free chalcopyrite 12 %, chalcopyrite-gangue 5 %, and chalcopyrite-pyrite and chalcopyrite-galena less than 0.2 % of the chalcopyrite in the Zn-concentrate. With the principal exception of sphalerite, the losses of chalcopyrite particles to the Zn-concentrate are largely independent of the accompanying mineral, but are principally dependent on the degree of chalcopyrite liberation (See Table 10), superimposed on poor selective flotation of chalcopyrite.

Only two categories exhibit significant losses to the tailings (6.69 % of the free, and 19.8 % of the ternary categories), which comprise 13.6 and 81.4 %, respectively of the chalcopyrite in the tailings. As unliberated grains comprise 89 %, and sub-middling grains comprise 75 % of the chalcopyrite in the tailings, the bulk of the ternary particles correspond to sub-middling chalcopyrite grains. Petrographic examination shows that the ternary particles consist largely of pyrite-gangue-chalcopyrite, pyrite-pyrrhotite-chalcopyrite, and sphalerite-pyrrhotite-chalcopyrite particles, in which the chalcopyrite grains are subordinate and fine-grained. These are only amenable to extremely fine regrinding. 'Over-sized' grains comprise a significant fraction of the free grains (not apparent from Table 17 of appendix 2), and thus these are also amenable to regrinding.

The host particle size distributions of chalcopyrite in the five end products, given in Table 2 of appendix D, are plotted as cumulative curves in Figure 2. The distributions for chalcopyrite in the Cu-concentrate, Pb-concentrate and tailings approximate to 80 % - 52 um, whereas that of chalcopyrite in the Zn-concentrate is 80 % - 40 um, yet that of the feed is 80 % - 32 um. The distribution in the feed is finer than those in the remaining four products, reflecting poor counting statistics for observations on chalcopyrite in the feed, and that image analysis data generated on the feed is typically non-representative (W. Petruk, pers. comm. 1989). It is noteworthy that 12 % of the chalcopyrite in the tailings occurs in particles less than 5 um (i.e. slime fraction). Although, minor 'over-sized' chalcopyrite is lost to the Zn-concentrate and tailings (See Plate 1I, 2A and 2B), the host particle size of chalcopyrite seems to have generally exerted negligible influence on the distribution of chalcopyrite in the end products.

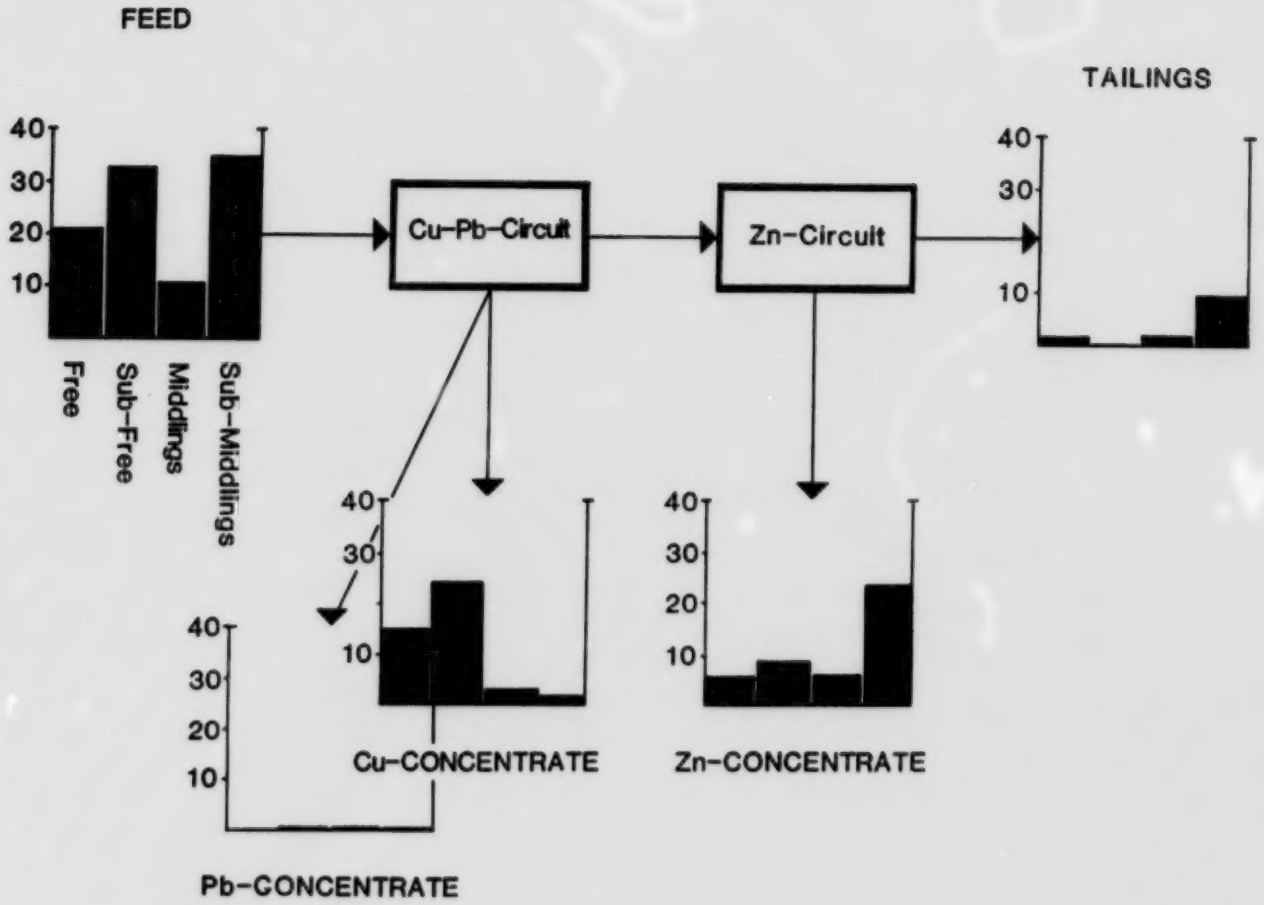

FIGURE 1.
THE MODAL FRACTION OF THE Cu RECOVERY MODELLED IN TERMS OF THAT OCCURRING AS FREE, SUB-FREE, MIDDLING AND SUB-MIDDLING GRAINS OF CHALCOPYRITE IN THE FIVE CHISEL LAKE END PRODUCTS.

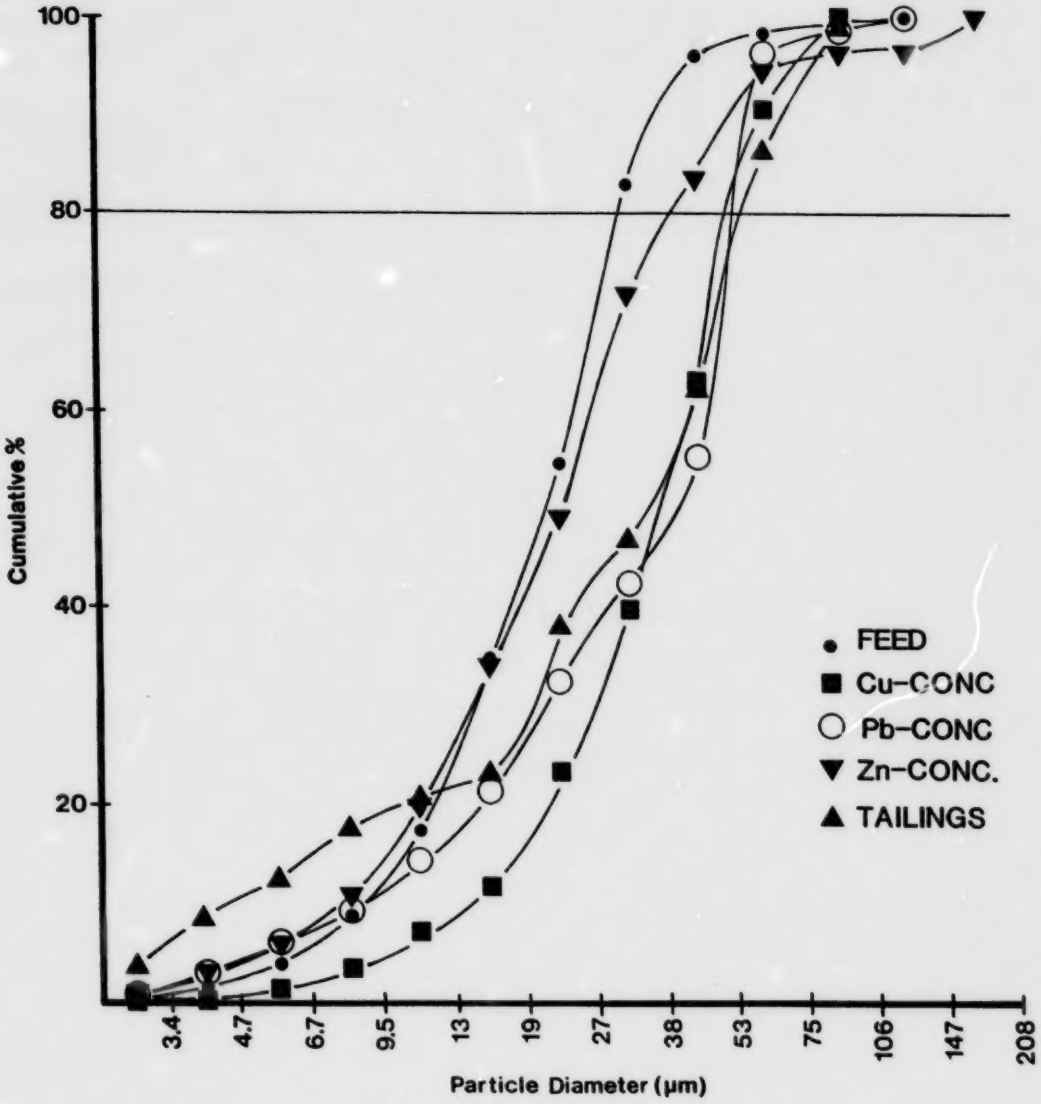

FIGURE 2.
THE HOST PARTICLE SIZE DISTRIBUTIONS OF CHALCOPYRITE IN THE FIVE CHISEL LAKE END PRODUCTS.

SPHALERITE

The raw modal fraction of the adjusted Zn assay occurring as free, unliberated, sub-free, middling and sub-middling sphalerite grains in each end product are given in Table 13. The adjusted equivalents of each of these categories are given in Table 14, whereas the corresponding recoveries are given in Table 15. The Zn recovery in each product was multiplied by the adjusted modal fraction of each category of sphalerite to give the adjusted modal fraction of the Zn recovery occurring as free, sub-free, middling and sub-middling sphalerite in each product. The latter data are given in Table 16, and plotted as histograms on a simplified circuit diagram in Figure 3. The first row of data in Table 16 gives the adjusted classification of sphalerite in the feed, which is: 49.2 % occur as free, 46.2 % as sub-free, 3.51 % as middling, and 1.06 % as sub-middling grains.

Of the sphalerite in the feed, 49.2 % occurs as free grains (i.e. % liberation), while a further 46.2 % occurs as sub-free grains. Thus, 95.4 % of the sphalerite occurs as free plus sub-free grains. This extremely high fraction of 'recoverable' grains of sphalerite indicates exceptionally high 'effective' liberation. Only 0.31 and 0.28 % of the free grains are recovered in the Cu- and Pb-concentrates, respectively, whereas 1.00 % and 1.65 % of the sub-free grains are recovered in these same concentrates. Consequently, only 0.59 % of the free, and 2.55 % of the sub-free grains of sphalerite are recovered prior to the Zn-circuit.

Approximately 98 % of the 'recoverable' sphalerite is directed to the Zn-circuit, indicating effective selective flotation and high sphalerite rejection from the Cu- and Pb-circuits. Subsequently, 98.1 % of the free and 96.6 % of the sub-free grains are recovered in the Zn-concentrate (See values in parentheses in Table 15), such that approximately 98.8 % of the 'recoverable' sphalerite entering the Zn-circuit is recovered in the Zn-concentrate. Thus, sphalerite rejection in the Cu-and Pb-circuits, and sphalerite flotation in the Zn-circuit are extremely efficient with respect to 'recoverable' sphalerite grains. However, because 'recoverable' grains comprise 95.4 % of the sphalerite in the feed, the minimal losses of 0.6, 0.9 and 1.2 % of these grains to the Cu- and Pb-concentrates and tailings, respectively, result in proportionally significant losses of 'recoverable' grains. The losses of 'recoverable' sphalerite account for approximately 85 % and 78 % of the sphalerite in the Cu- and Pb-concentrates, respectively, but only 35 % of the sphalerite in the tailings. Thus, although the losses of 'recoverable' sphalerite are well within routine and acceptable limits these losses constitute a high percentage of the sphalerite lost to the Cu- and Pb-concentrates and tailings.

In addition to the 95.4 % 'recoverable' sphalerite in the feed, 3.51 % occurs as middling grains. Of these 59.9 % are recovered in the Zn-concentrate, corresponding to 2.10 % of the sphalerite in the feed. The Cu- and Pb-concentrates recover 1.90 and 5.19 %, respectively of the middling sphalerite. These losses correspond to 0.07 and 0.18 %, respectively of the sphalerite in the feed, and account for approximately 11 and 16 %, of the sphalerite in the Cu- and Pb-concentrates,

TABLE 13

RAW SPHALERITE LIBERATIONS IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Total Zn Assay	Free	Unliberated	Sub-free Middling	Sub-middling
		(Modal Fraction of the Zn assay)			
Feed	16.7	9.45	7.27	6.67	0.50	0.10
Cu-Conc.	13.9	3.20	10.7	8.80	1.42	0.48
Pb-Conc.	10.4	1.25	9.15	6.84	1.65	0.65
Zn-Conc.	53.9	20.0	33.9	32.5	1.36	0.10
Tailings	0.78	0.16	0.63	0.10	0.30	0.22

TABLE 14

ADJUSTED SPHALERITE LIBERATIONS IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Total Zn Assay	Free	Unliberated	Sub-free Middling	Sub-middling
		(Modal Fraction of the Zn assay)			
Feed	16.7	8.14	8.35	7.64	0.58	0.18
Cu-Conc.	13.9	3.20	10.7	8.79	1.42	0.48
Pb-Conc.	10.4	1.25	9.13	6.83	1.63	0.64
Zn-Conc.	53.9	27.1	26.0	25.0	1.18	0.10
Tailings	0.78	0.16	0.62	0.10	0.28	0.20

respectively. Furthermore, 33.0 % of the middling sphalerite is rejected to the tailings, corresponding to 1.22 % of the sphalerite in the feed, and accounting for approximately 39 % of the sphalerite in the tailings. Middling grains are the principal category of particle amenable to increased liberation and recovery through regrinding. Because 3.51 % of the sphalerite in the feed occurs as middling grains, of which 40 % are not recovered to the Zn-concentrate, enhanced liberation and recovery from these grains by regrinding is not expected to be significant (i.e. < 1.5 %).

Of the 1.06 % of the sphalerite in the feed that occurs as sub-middling grains, only 0.17 % (i.e. 15.9 %) is recovered in the Zn-concentrate. The losses of 2.12 % to the Cu-concentrate, and 6.72 % to the Pb-concentrate, only account for 0.02 and 0.07 %, respectively of the sphalerite in the feed, and are thus insignificant. The loss of 75.3 % of the sub-middling

TABLE 15

RECOVERY OF SPHALERITE LIBERATIONS IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Zn Recovery	Free	Unliberated	Sub-free	Middling	Sub-middling
		Recovery (%)				
Feed	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	0.65	0.31	1.00	0.90	1.90	2.12
Pb-Conc.	1.15	0.28	2.01	1.65	5.19	6.72
Zn-Conc.	95.0	98.1	91.9	96.6	59.9	15.9
	(98.1)	(98.7)	(94.8)	(99.1)	(64.5)	(17.4)
Tailings	3.17	1.30	5.05	0.89	33.0	75.3

Note: Values in parenthesis show the recovery in the Zn-concentrate of each variable as a function of that in the Zn-circuit feed.

grains to the tailings, accounts for 0.84 % of the sphalerite in the feed, and 27 % of the sphalerite in the tailings. Although 84.1 % of the sub-middling sphalerite are not recovered to the Zn-concentrate, these losses only account for 0.9 % of the sphalerite in the feed, and are essentially

TABLE 16

RECOVERY OF THE Zn ASSAY IN THE FIVE CHISEL LAKE END PRODUCTS IN TERMS OF THE MODAL FRACTION OF SPHALERITE OCCURRING AS FREE, SUB-FREE, MIDDLING AND SUB-MIDDLING GRAINS.

PRODUCT	Zn Recovery	Free	Sub-free	Middling	Sub-middling
		Recovery (%)			
Feed	100.0	49.2	46.2	3.51	1.06
Cu-Conc.	0.65	0.15	0.41	0.07	0.02
Pb-Conc.	1.15	0.14	0.76	0.18	0.07
Zn-Conc.	95.0	48.2	44.5	2.10	0.17
Tailings	3.17	0.68	0.43	1.22	0.84

unrecoverable without recourse to extremely fine regrinding.

The raw mineral association data for sphalerite (Table 3 of appendix C) were material balance adjusted (Table 4 of appendix C) and recoveries of these were calculated (See Table 17). Also given on the first and last rows of data in Table 17 are the modal percentages of sphalerite occurring in each specific association category of sphalerite in the corresponding product. It is apparent from these data that 49.5 % of the sphalerite is free (as discussed above), and that the largest fractions of the unliberated grains occur as binary sphalerite-gangue (i.e. 20.6 %), ternary particles (i.e. 20.5 %), with lesser fractions as binary particles of sphalerite-chalcopyrite (i.e. 8.98 %), sphalerite-pyrite

TABLE 17

RECOVERY OF THE MINERAL ASSOCIATIONS OF SPHALERITE IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Zn Recovery	Free Sph	Sph+Py	Sph+Gan	Sph+Cpy	Sph+Gal	Ternary Sph
Feed	----	49.5	0.29	20.6	8.98	0.15	20.5
Feed	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	0.65	0.31	0.11	0.36	1.96	2.02	1.22
Pb-Conc.	1.15	0.28	2.69	0.04	0.13	48.6	4.54
Zn-Conc.	95.0	98.1	16.7	98.6	96.6	46.6	84.3
Tailings	3.17	1.30	80.5	1.04	1.33	2.77	9.98
Tailings	----	20.2	7.11	6.55	3.66	0.13	62.4

Note: The first and last rows of data present the adjusted modal percents of sphalerite occurring in specific association categories in the feed and tailings, respectively. These were calculated by dividing the Zn assay by the corresponding adjusted modal fraction of the Zn assay occurring in each category (See Table 4 of appendix C).

(i.e. 0.29 %) and sphalerite-galena (i.e. 0.15 %).

Each of the above categories (and notably including the sphalerite-chalcopyrite category) show losses to the Cu-concentrate that are less than 2.02 %, and which each account for less than 0.25 % of the sphalerite in the feed. The free sphalerite and sphalerite-gangue categories show recoveries in the Zn-concentrate of greater than 98 %, whereas the sphalerite-chalcopyrite category shows a recovery of 96.6 % in the Zn-

concentrate, but 1.96 % in the Cu-concentrate. Significantly, only 84.3 % of the ternary sphalerite (the third largest category) is recovered in the Zn-concentrate, with 4.54 % and 9.98 % lost in the Pb-concentrate and tailings, respectively. The latter loss to the tailings corresponds to 2.1 % of the sphalerite in the feed, and accounts for 62.4 % of the sphalerite in the tailings. As 65 % of the sphalerite in the tailings occurs as middling and sub-middling grains, these probably largely correspond to ternary sphalerite.

Only 16.7 % of the sphalerite-pyrite category is recovered in the Zn-concentrate, with 80.5 % rejected to the tailings. The latter grains consist largely of sub-middling sphalerite interstitial to host pyrite (See Plate 2D). Because the sphalerite-pyrite category accounts for only 0.29 % of the sphalerite in the feed, these high losses account for 7.11 % of the sphalerite in the tailings. The sphalerite-galena category is largely recovered in the Pb- and Zn-concentrates (i.e. 48.6 and 46.6 %, respectively), with only minor losses to the tailings (i.e. 2.77 %). However, because this category comprises only 0.15 % of the sphalerite in the feed, the losses to the Pb-concentrate (See Plate 2F), account for only 0.07 % of the sphalerite in the feed.

It is apparent from the mineral association analysis of sphalerite that the distribution of sphalerite in the end products as a function of mineral association, indicates two principal losses to the tailings: (1) free sphalerite, and (2) ternary sphalerite, together accounting for 82.6 % of the sphalerite in the tailings, and corresponding to 2.6 % of the sphalerite in the feed. A third fraction of lost sphalerite is that of ternary sphalerite to the Pb-concentrate, accounting for 81 % of the sphalerite in the Pb-concentrate, and corresponding to 0.9 % of the sphalerite in the feed. Thus, these three fractions of sphalerite account for 3.5 % of the 5 % sphalerite (i.e. 70 %) that is not recovered in the Zn-concentrate.

The liberation and mineral association analyses of sphalerite (See Tables 16 and 17), show that approximately 20 % of the sphalerite in the tailings is free. The liberation analysis shows that 65 % of the sphalerite in the tailings occurs as middling and sub-middling grains, whereas association analysis also shows that 62 % occurs as ternary particles (See Table 17), which thus probably correspond to the middling and sub-middling grains. It is apparent from Table 3 of appendix C that the bulk of the ternary sphalerite particles in the tailings consist of sphalerite-pyrite-gangue-(±other). Petrographic examination confirms this, and that the other associated minerals in the ternary particles are chalcopyrite, pyrrhotite and/or galena. The petrographic examination of the tailings also indicates that the fraction of sphalerite occurring as 'recoverable' grains is greater than the 35 % indicated by the material balance of the sphalerite liberation (See Table 16).

The host particle size distributions of sphalerite in the five end products, given in Table 3 of appendix D are plotted as cumulative curves in Figure 4. Sphalerite in the feed has a distribution of 80 % -50 um, whereas that in both the Cu- and Zn-concentrates is slightly finer (i.e. 80 % -44 um). This results from the preferential loss of the coarser

sphalerite host particles to the Pb-concentrate and tailings (i.e. 80 % -62 um and 80 % -120 um, respectively). The distributions in each product show that the host particles of sphalerite are largely medium-grained with a negligible slime component. However, in the tailings 40 % of the sphalerite host particles are 'over-sized' (i.e. + 100 um). Petrographic analysis indicates that the dominant fraction of the losses of 'recoverable' grains, which comprise approximately 35 % of the sphalerite in the tailings, are 'over-sized' (See Plate 2C and 2D). Thus, the loss of 'recoverable' grains to the tailings is largely attributed to the low recovery of grains which fall above the routinely floatable particle size limit (i.e. < 100 um). This is not apparent from the classification and size data for sphalerite in the tailings (Table 18 of appendix B). However, because the 'over-sized', 'recoverable' grains of sphalerite were concentrated on the margin of the section due to fractionation during sample preparation, these grains were not included in the area analysed by image analysis. The losses of middling and sub-middling grains of sphalerite to the tailings are partly dependent on both the host particle size (i.e. > 100 um) and degree of liberation (i.e. < 70 %).

From Table 16 four principal fractions of sphalerite not recovered to the Zn-concentrate are recognized: (1) free and sub-free grains in the tailings (i.e. 1.11 %), (2) sub-free grains in the Pb-concentrate (i.e. 0.76 %), (3) middling grains in the tailings (i.e. 1.22 %), and (4) sub-middling grains in the tailings (i.e. 0.84 %). Middling grains constitute the largest fraction and are most amenable to regrinding. The smaller fraction of sub-middling grains are only amenable to extremely fine regrinding. As stated above, 'over-sized', 'recoverable' grains comprise a significantly larger fraction of the sphalerite in the tailings than indicated by image analysis. Much of the 'recoverable' grains are therefore also amenable to regrinding. Thus, approximately 3 to 4 % of the 5 % of sphalerite not recovered in the Zn-concentrate is amenable to regrinding. Regrinding can (1) improve liberation from middling and sub-middling grains, and (2) reduce the losses of 'over-sized', 'recoverable' grains, whose rejection is independent of liberation.

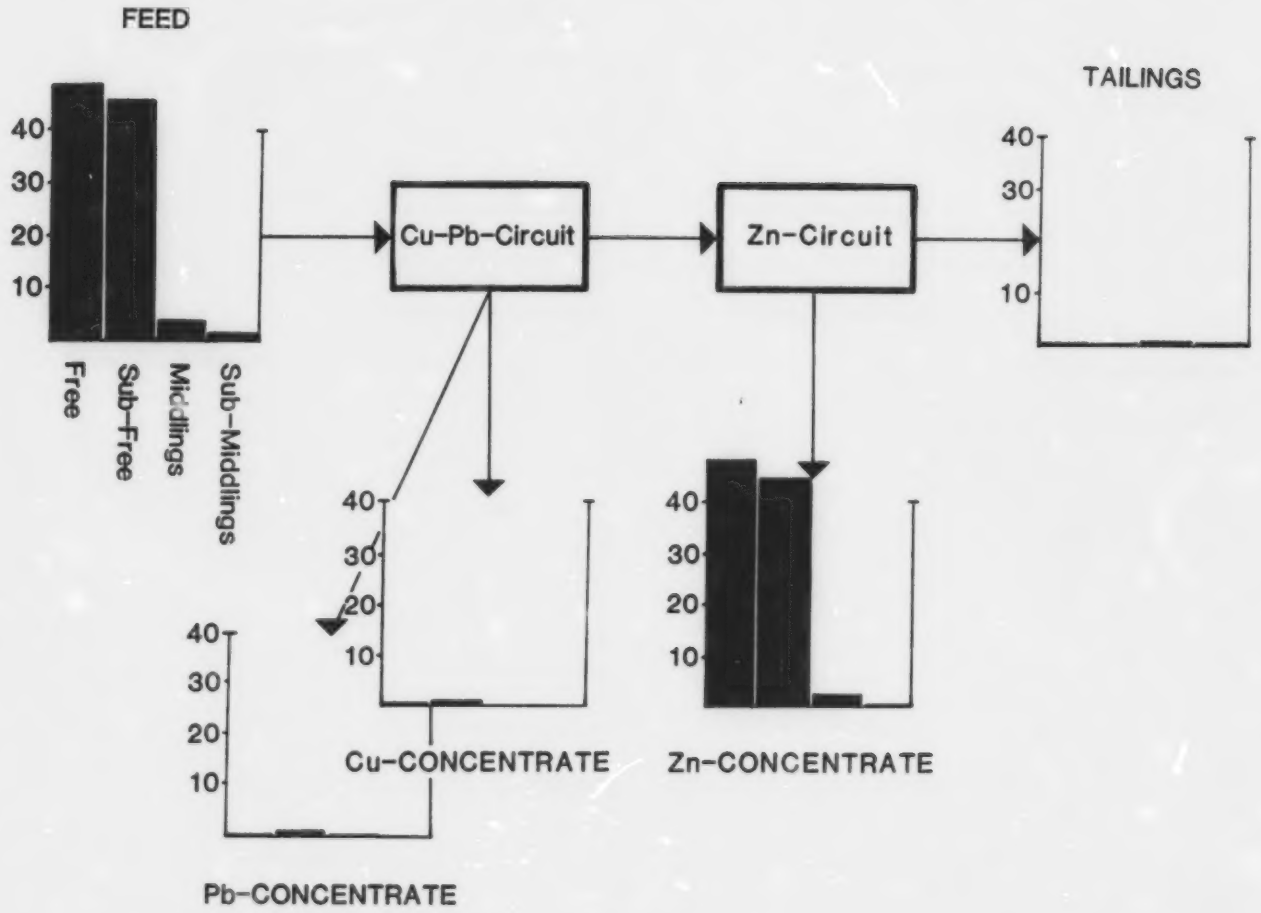

FIGURE 3.
THE MODAL FRACTION OF THE Zn RECOVERY MODELLED IN TERMS OF THAT OCCURRING AS FREE, SUB-FREE, MIDDLING AND SUB-MIDDLING GRAINS OF SPHALERITE IN THE FIVE CHISEL LAKE END PRODUCTS.

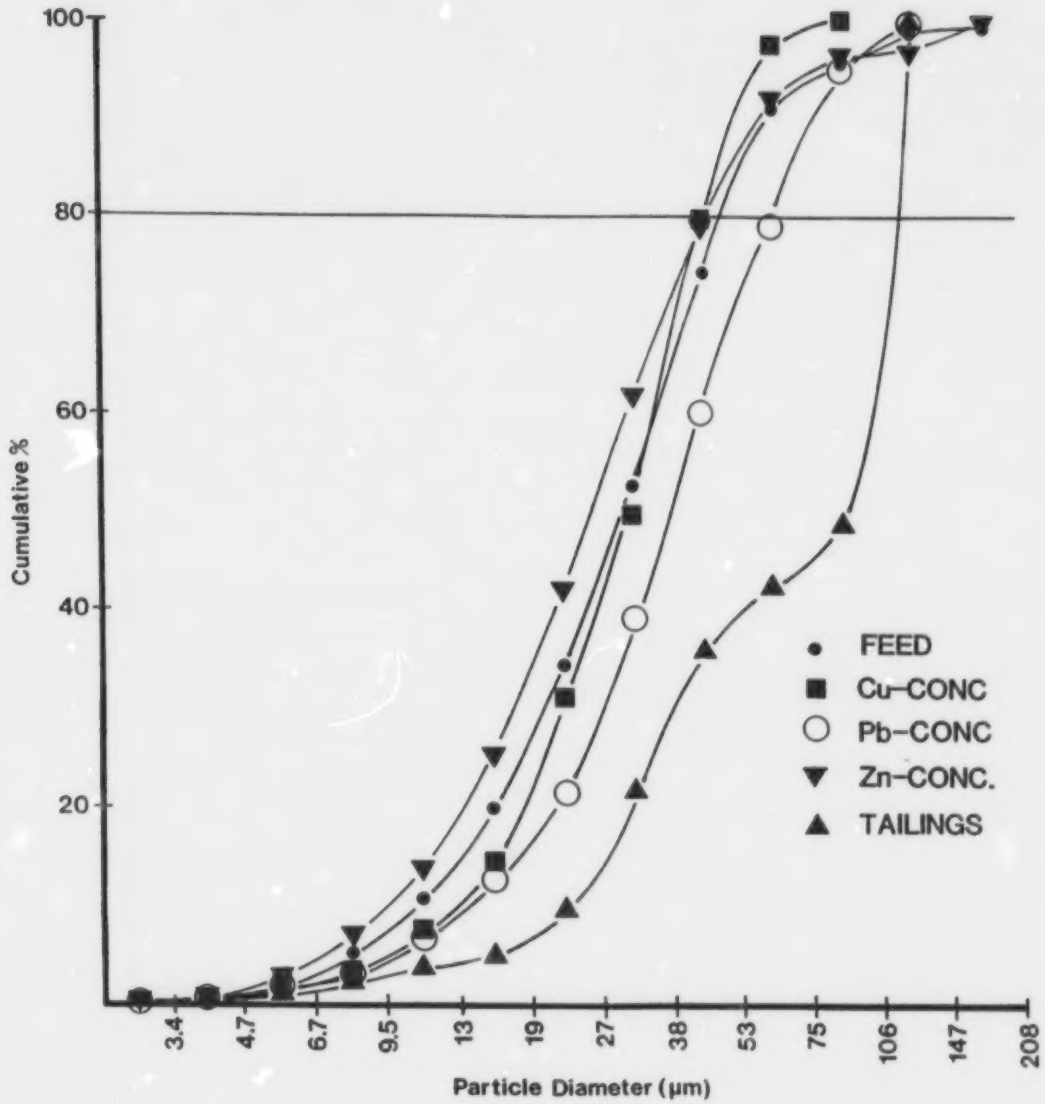

FIGURE 4.
THE HOST PARTICLE SIZE DISTRIBUTIONS OF SPHALERITE IN THE FIVE CHISEL LAKE END PRODUCTS.

GALENA

The raw modal fraction of the adjusted Pb assay occurring as free, unliberated, sub-free, middling and sub-middling galena grains in each end product are given in Table 18. The adjusted equivalents of each of these categories are given in Table 19, whereas the corresponding recoveries of these are given in Table 20. The Pb recovery in each product was multiplied by the adjusted modal fraction of each category of galena to give the adjusted modal fraction of the Pb recovery occurring as free, sub-free, middling and sub-middling galena in each product. The latter data are given in Table 21, and plotted as histograms on a simplified circuit diagram in Figure 5. The first row of data in Table 21 gives the adjusted classification of galena in the feed, which is: 52.1 % occur as free, 25.7 % as sub-free, 9.41 % as middling and 12.9 % as sub-middling grains.

Although 52.1 % of the galena in the feed occurs as free grains (i.e. % liberation), a further 25.7 % occurs as sub-free grains. Thus, 77.8 % of the galena occurs as free plus sub-free grains. This relatively high fraction of 'recoverable' grains of galena indicates moderate 'effective' liberation. While 92.1 % of the free grains are recovered in the Pb-concentrate, only 2.28, 3.11 and 2.57 % are recovered in the Cu- and Zn-concentrates and tailings, respectively. However, only 58.3 % of the sub-free grains are recovered in the Pb-concentrate, with losses of 4.06, 35.1 and 2.60 % to the Cu- and Zn-concentrates, and tailings, respectively. Consequently, 80.7 % of the 'recoverable' grains are recovered in the Pb-concentrate, accounting for 62.8 % of the galena in the feed, and 89 % of the galena recovered to the Pb-concentrate. The Cu-concentrate recovers a further 2.88 % of the 'recoverable' grains, accounting for 2.24 % of the galena in the feed, and 78 % of the galena lost to the Cu-concentrate. A further 14.1 % of the 'recoverable' grains are lost to the Zn-concentrate, accounting for 11 % of the galena in the feed, and 83 % of the galena in the Zn-concentrate. In addition, 2.51 % of the 'recoverable' grains are rejected to the tailings, accounting for 1.95 % of the galena in the feed, but only 15 % of the galena in the tailings. Because the 'recoverable' grains of galena constitute 77.8 % of the galena in the feed, the loss of 14.1 % of these grains to the Zn-concentrate, represents the single largest fraction of galena not recovered in the Pb-concentrate. The losses of 'recoverable' grains to the Cu-concentrate and tailings correspond to only 2.24 and 1.95 %, respectively of the galena in the feed, and account for 78 % and 15 % of the galena in these same products. Thus, 78 % and 15 % of the galena lost to the Cu-concentrate and tailings, respectively is essentially independent of liberation, and is expected in terms liberation, to be recovered in the Pb-concentrate. However, these losses only constitute 2.88 and 2.51 %, respectively of the 'recoverable' grains in the feed, and are thus within acceptable limits of such losses.

In addition to the 77.8 % recoverable galena in the feed, 9.41 % occurs as middling grains. Only 39.6 % of these grains are recovered in the Pb-concentrate, corresponding to 3.72 % of the galena in the feed. The Cu-concentrate recovers 2.90 % of the middling galena, accounting for 0.28 % of the galena in the feed, and 9.8 % of the galena in the Cu-concentrate. Furthermore, 15.3 % of the middling galena is rejected to the Zn-

TABLE 18

RAW GALENA LIBERATIONS IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Total Pb Assay	Free	Unliberated	Sub-free	Middling	Sub-middling
		(Modal Fraction of the Pb assay)				
Feed	0.71	0.413	0.298	0.118	0.040	0.138
Cu-Conc.	2.60	1.080	1.520	0.954	0.257	0.312
Pb-Conc.	27.0	16.90	10.10	6.910	1.700	1.490
Zn-Conc.	0.32	0.039	0.280	0.227	0.035	0.019
Tailings	0.14	0.014	0.126	0.007	0.042	0.078

TABLE 19

ADJUSTED GALENA LIBERATIONS IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Total Pb Assay	Free	Unliberated	Sub-free	Middling	Sub-middling
		(Modal Fraction of the Pb assay)				
Feed	0.71	0.370	0.343	0.182	0.067	0.092
Cu-Conc.	2.60	1.081	1.518	0.950	0.257	0.313
Pb-Conc.	27.0	18.42	8.917	5.746	1.433	1.525
Zn-Conc.	0.32	0.039	0.277	0.217	0.035	0.019
Tailings	0.14	0.014	0.125	0.007	0.042	0.082

TABLE 20

RECOVERY OF GALENA LIBERATIONS IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Pb Recovery	Free	Unliberated	Sub-free	Middling	Sub-middling
		Recovery (%)				
Feed	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	2.86	2.28	3.45	4.06	2.90	2.66
Pb-Conc.	70.5	92.1	48.1	58.3	39.6	30.8
Zn-Conc.	13.3	3.11	23.8	35.1	15.3	6.14
Tailings	13.4	2.57	24.7	2.60	42.1	60.4

concentrate, accounting for to 1.49 % of the galena in the feed, and 11 % of the galena in the Zn-concentrate. The largest fraction of middling grains is lost to the tailings (i.e. 42.1 %), and accounts for 3.86 % of the galena in the feed, and 29 % of the galena in the tailings. This represents the third largest fraction of galena not recovered to the Pb-concentrate. Middling grains are the principal category of particle amenable to increased liberation and recovery through regrinding. Although only 9.41 % of the galena in the feed occurs as middling grains, 60.3 % of these are lost to the Cu- and Zn-concentrates and tailings combined, such that enhanced liberation and recovery from these grains (alone) by fine regrinding is nominally expected to be significant (i.e. ≤ 5 %).

Of the 12.9 % of the galena in the feed that occurs as sub-middling grains, 3.96 % (i.e. 30.8 %) is recovered in the Pb-concentrate, 0.34 % (i.e. 2.66 %) in the Cu-concentrate, 0.82 % (i.e. 6.14 %) in the Zn-concentrate, and 7.58 % (i.e. 60.4 %) in the tailings. The losses of sub-middling galena to the Cu- and Zn-concentrate combined constitute only 1.62 % of the galena in the the feed, whereas those rejected to the tailings constitute 7.58 % of the galena in the feed, and 57 % of the galena in the tailings. The latter losses of sub-middling grains of galena constitute the second largest fraction of galena not recovered to the Pb-concentrate. These lost sub-middling galena grains are essentially

TABLE 21

RECOVERY OF THE Pb ASSAY IN THE FIVE CHISEL LAKE END PRODUCTS IN TERMS OF THE MODAL FRACTION OF GALENA OCCURRING AS FREE, SUB-FREE, MIDDLING AND SUB-MIDDLING GRAINS.

PRODUCT	Pb Recovery	Free	Sub-free	Middling	Sub-middling
		Recovery (%)			
Feed	100.0	52.1	25.7	9.41	12.9
Cu-Conc.	2.86	1.19	1.05	0.28	0.34
Pb-Conc.	70.5	47.9	14.9	3.72	3.96
Zn-Conc.	13.3	1.67	9.32	1.49	0.82
Tailings	13.4	1.30	0.65	3.86	7.58

unrecoverable without recourse to fine regrinding.

The raw mineral association data for galena (Table 5 of appendix C) were material balance adjusted (Table 6 of appendix C) and recoveries of these were calculated (See Table 22). Also given on the first and last rows of data in Table 22 are the modal percentages of galena occurring in each specific association category of galena in the corresponding product.

It is apparent from Table 22 that the bulk of the galena is free (i.e. 52.2 %), and that the largest fraction of the unliberated grains occur as ternary particles (i.e. 30.4 %), with lesser fractions as binary particles of galena-gangue (i.e. 14.8%), galena-pyrite (i.e. 1.34 %), galena-

TABLE 22

RECOVERY OF THE MINERAL ASSOCIATIONS OF GALENA IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Pb Recovery	Free Gal	Gal+Py	Gal+Gan	Gal+Sph	Gal+Cpy	Ternary Gal
Feed	----	52.2	1.34	14.8	1.00	0.34	30.4
Feed	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	2.86	2.28	0.16	1.49	7.00	13.3	4.20
Pb-Conc.	70.5	92.1	92.3	38.1	75.0	49.3	54.3
Zn-Conc.	13.3	3.11	3.11	55.9	8.35	12.1	7.81
Tailings	13.4	2.57	7.23	4.50	9.63	26.9	33.7
Tailings	----	10.7	0.76	5.34	0.76	0.69	81.7

Note: The first and last rows of data present the adjusted modal percents of galena occurring in specific association categories in the feed and tailings, respectively. These were calculated by dividing the Pb assay by the corresponding adjusted modal fraction of the Pb assay occurring in each category (See Table 6 of appendix C).

sphalerite (i.e. 1.00 %) and galena-chalcopyrite (i.e. 0.34 %).

Only three of the above categories are volumetrically significant (i.e. > 1.5 %), such that only the free, ternary and galena-gangue categories need be considered. As discussed above, the free grains consititute 52.2 % of the galena in the feed, of which 92.1 % are recovered in the Pb-concentrate. The losses of free grains to each of the other products are less than 3.11 %, together account for less than 4.5 % of the galena in the feed, and are thus relatively insignificant. Ternary particles comprise 30.4 % of the galena in the feed, and of which only 54.3 % are recovered in the Pb-concentrate. The principal loss from this category is the 33.7 % of the ternary grains rejected to the tailings, accounting for 10.3 % of the galena in the feed, and 81.7 % of the galena in the tailings. The galena-gangue category comprises 14.8 % of the galena in the

feed, and of which the principal loss is of 55.9 % to the Zn-concentrate. This lost fraction accounts for 8.3 % of the galena in the feed, and 62 % of the galena in the Zn-concentrate. Thus, on the basis of mineral association, two principal fractions of galena are unrecovered to the Pb-concentrate. These are: (1) ternary galena particles in the tailings, and (2) galena-gangue particles in the Zn-concentrate. These losses combined account for 18.5 % of the galena in the feed, corresponding to 63 % of the galena unrecovered to the Pb-concentrate.

The host particle size distributions of galena in the five end products, given in Table 4 of appendix D, are plotted as cumulative curves in Figure 6. The distribution of galena in the feed is 80 % -25 um. The distribution in the feed is finer than those in the remaining four products, and as stated earlier, reflects poor counting statistics for observations on galena in the feed, and that image analysis data generated on the feed is typically non-representative. The distribution for galena in the Pb-concentrate is relatively smooth compared to those of the other products, is defined as 80 % - 56 um, and is essentially comparable to those in the Zn-concentrate and tailings, although these are more irregular. However, the distribution in the Cu-concentrate is relatively smooth and consistently finer than that in the Pb-concentrate. This is consistent with the fine size of 'recoverable' grains (See Table 7 of appendix B), which comprise 78 % of the galena in the Cu-concentrate. Thus, the only systematic trend recognised in the distribution of galena in the end products as a function of host particle size is that finer, largely 'recoverable' galena preferentially float in the Cu-circuit. However, it is also stressed that galena lost to the Zn-concentrate is largely medium-grained and 'recoverable', and is thus expected to have been recovered in the Pb-circuit. Furthermore, galena in the tailings is also medium-grained, but occurs largely as middling and sub-middling grains, and on the basis of liberation is not expected to be recovered in the Pb-concentrate.

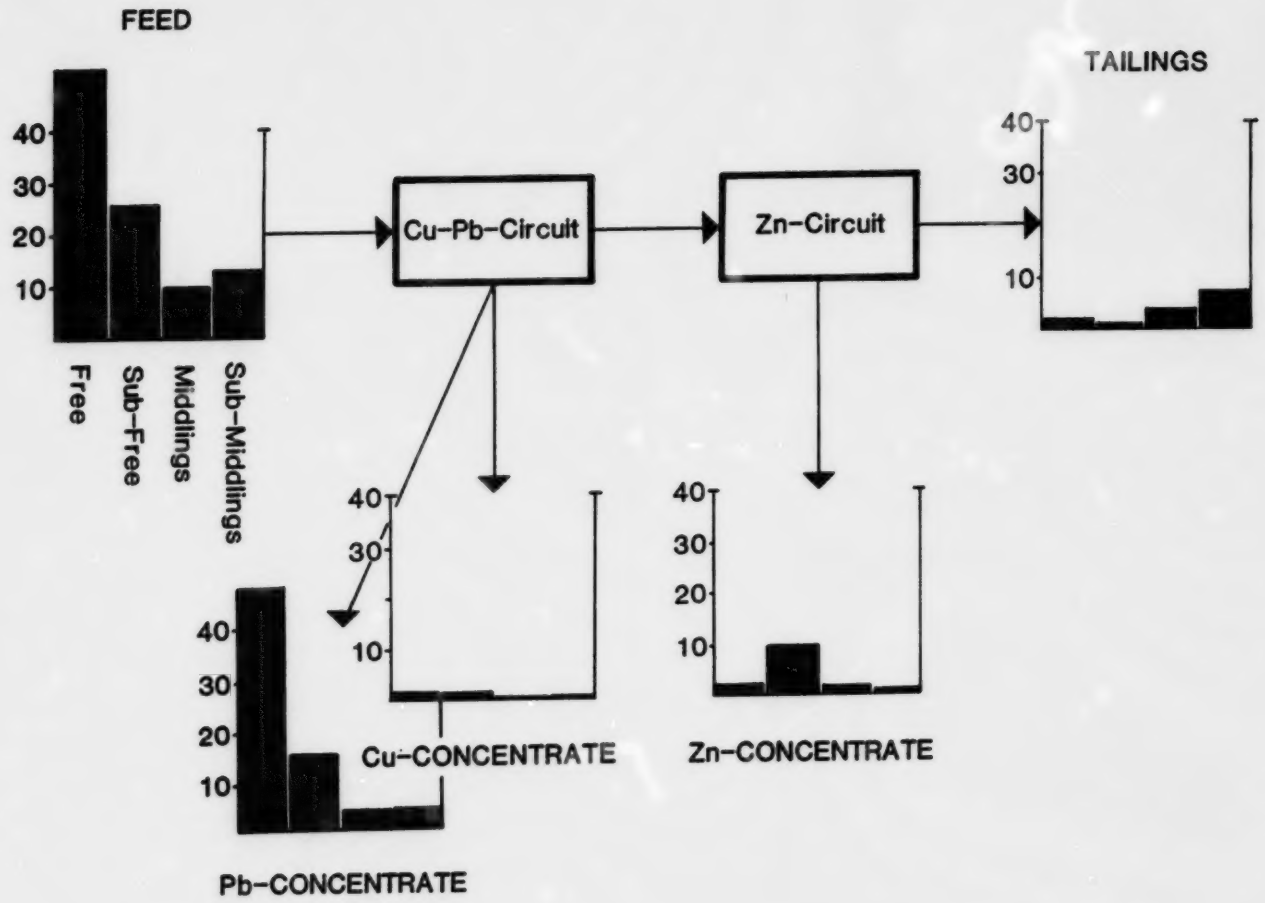

FIGURE 5.
THE MODAL FRACTION OF THE Pb RECOVERY MODELLED IN TERMS OF THAT OCCURRING AS FREE, SUB-FREE, MIDDLING AND SUB-MIDDLING GRAINS OF GALENA IN THE FIVE CHISEL LAKE END PRODUCTS.

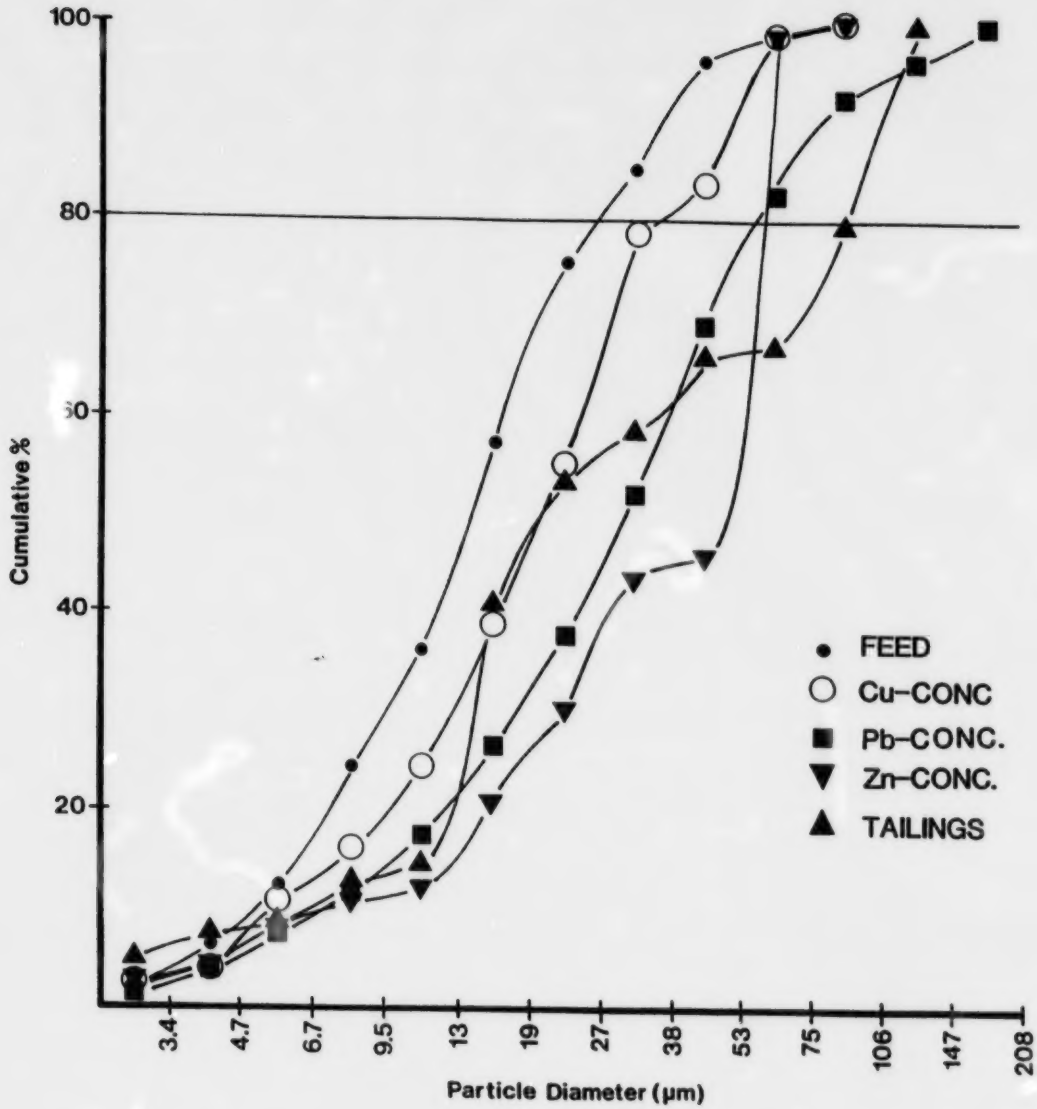

FIGURE 6.
THE HOST PARTICLE SIZE DISTRIBUTIONS OF GALENA IN THE FIVE CHISEL LAKE END PRODUCTS.

PYRITE

The raw modal fractions of the pyrite modal quantities occurring as free, unliberated and sub-free grains in each end product are given in Table 23. The adjusted equivalents of each of these categories and the corresponding recoveries of these are also given in Table 23. The % free, % unliberated and % sub-free were calculated from the adjusted modal fractions of pyrite occurring as free, unliberated and sub-free grains in the feed, and these are given on the first row of data in Table 23. It is apparent from these data that the liberation of pyrite in the feed is 38.6 %, whereas an additional 58.4 % occur as sub-free grains. Thus, 97.0 % of the pyrite in the feed occurs as free plus sub-free grains. Assuming relatively low recoveries of sub-middling grains of floatable minerals (e.g. sub-middling chalcopyrite to to the Cu-concentrate), which may be locked with sub-free pyrite, extremely high rates of pyrite

TABLE 23

PYRITE LIBERATIONS IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Raw Modal Fractions			Adjusted Modal Fractions			Recovery (%)		
	Free	Locked	Sub-Free	Free	Locked	Sub-Free	Free	Locked	Sub-Free
Feed	31.5	68.5	64.0	38.6	61.5	58.4	----	----	----
Feed	11.9	25.9	24.2	13.8	22.0	20.9	100.0	100.0	100.0
Cu-Conc.	2.77	8.63	6.53	2.77	8.63	6.53	0.16	0.30	0.25
Pb-Conc.	8.57	42.8	40.3	8.55	43.0	40.5	1.15	3.61	3.55
Zn-Conc.	0.51	2.98	2.32	0.51	3.00	2.33	1.09	4.01	3.29
Tails.	25.7	27.0	25.8	19.8	29.9	28.6	97.6	92.1	92.9

rejection to the tailings are expected.

The 38.6 % liberation of pyrite in the feed is relatively low. However, including 58.4 % of the pyrite in the feed that occurs as sub-free grains, the effective liberation of pyrite is 97.0 %. The corresponding grains are nominally expected to be rejected to the tailings under relatively standard flotation conditions. However, 94.6 % of the pyrite is rejected to the tailings (See Table 7), stemming largely from the 97.6 and 92.9 % rejection of free and sub-free pyrite, respectively. Thus, 94.7 % of free plus sub-free pyrite is rejected to the tailings. The pyrite content of the Cu-concentrate is 11.4 % (See Table 6), although only 0.24 % of the pyrite in the feed is recovered in the Cu-concentrate

(See Table 7). Similarly, the pyrite content of the Pb-concentrate is 51.3 %, although only 2.48 % of the pyrite in the feed is recovered in the Pb-concentrate. In contrast, the pyrite content of the Zn-concentrate is 3.49 %, yet 2.73 % of the pyrite in the feed is recovered in the Zn-concentrate.

The quantities of pyrite are sufficient in both the Cu- and Pb-concentrates (i.e. 11.4 and 51.3 %, respectively) to substantially lower the concentrate grades. However, free plus sub-free grains account for approximately 82, 95 and 81 % of the pyrite in the Cu-, Pb- and Zn-concentrates, respectively. As the rejection of free plus sub-free pyrite grains is high (i.e. 94.7 %), yet this category of pyrite predominates in the concentrates, a further decrease the recovery of pyrite is largely independent of liberation.

CONCLUSIONS

1. Material balance calculated composition of the feed in terms of the valuable metals, shows that the feed contains:

   16.7 % Zn
   0.35 % Cu
   0.71 % Pb
   0.033 % Cd
   38.1 ppm Ag
   2.52 ppm Au

   The feed contains high levels of Zn and relatively normal levels of Cu, Ag and Au relative to 'normal' feeds.

2. Material balance modelling of the raw chemical assays for the valuable metals Cu, Zn, Au, Ag and Pb through the circuit under simulated steady state conditions gives the following recoveries (%) :

	Cu-Conc.	Pb-Conc.	Zn-Conc.	Tailings.
Zn	0.65	1.15	95.0	3.17
Cu	42.6	1.48	42.9	13.0
Pb	2.86	70.5	13.3	13.4
Au	16.3	5.02	42.7	36.0
Ag	22.0	24.9	35.0	18.1
Cd	0.69	1.24	93.9	4.14

3. The distribution of the recoveries of each of the 8 elements indicates five principal groups of elements exhibiting relatively uniform distribution in the products. These are:

   a) Group 1: Exhibit high recoveries in the Zn-concentrate (approx. 42.5 %), with moderate to high recoveries in the Cu-concentrate and tailings i.e. Cu and Au.

   b) Group 2: Exhibit relatively uniform recoveries in the all end products (> 18, < 35 %) i.e. Ag.

   c) Group 3: Exhibit very high recoveries to the Zn-concentrate (93-95 %) i.e. Zn and Cd.

   d) Group 4: Exhibit high recoveries to the Pb-concentrate (70.5 %), with moderately low recoveries in the other end products i.e. Pb.

   e) Group 5: Exhibit high rejection to the tailings (> 60, < 85 %), with moderate recoveries in the Zn-concentrate i.e. Fe and S.

4. The mineralogical composition (in vol %) of the feed was calculated by material balance adjusting the image analysis data. This is given below:

    31.8 % Gangue (i.e. silicates and carbonates)
    37.8 % Pyrite (including minor magnetite and marcasite)
    27.1 % Sphalerite
    0.95 % Pyrrhotite
    0.91 % Chalcopyrite
    0.568 % Galena
    0.290 % Arsenopyrite

    The quantities of the trace minerals tetrahedrite, stannite, cassiterite, pyrargyrite, electrum, molybdenite, native bismuth and altaite (whose relative abundances occur in the order listed) were not determined.

5. The distribution of the recoveries of each of the 7 minerals whose modal quantities were determined, and which were material balance modelled through the circuit, indicate four principal groups of minerals, each with relatively uniform flotation behaviour. These are:

    a) Group 1: Inert minerals which are principally rejected to the tailings (> 70 %) i.e. gangue, pyrite, pyrrhotite and arsenopyrite.

    b) Group 2: Minerals with moderately high recoveries in the Cu- and Zn-concentrates (approx. 44 %) i.e. chalcopyrite only.

    c) Group 3: Minerals principally recovered in the Zn-concentrate (97 %) i.e. sphalerite only.

    d) Group 4: Minerals principally recovered in the Pb-concentrate (75%) i.e. galena only.

6. The liberation (i.e. % free) of chalcopyrite, sphalerite, galena and pyrite in the feed are 21.4, 49.2, 52.1 and 38.6 %, respectively, whereas the 'effective' liberation (i.e. % free plus sub-free) of these same minerals are 54.4, 95.4, 77.8 and 97 %, respectively.

7. The simplified classification of chalcopyrite in the feed, in terms of the liberation categories is 21.4 % free, 33.0 % sub-free, 10.8 % middling and 35.0 % sub-middling grains. This is shown in the table below, along with the recoveries of each category.

CHALCOPYRITE	FREE	SUB-FREE	MIDDLING	SUB-MIDDLING	TOTAL DERIVED Cu ASSAY	Cu REC.
LIBERATION in the float feed	21.4	33.0	10.8	35.0	0.35	100.0
RECOVERY in the Cu-Conc.	68.9	72.9	25.3	4.19	18.6	42.6
RECOVERY in the Pb-Conc.	0.49	1.50	4.59	1.26	0.28	1.48
RECOVERY in the Zn-Conc.	23.9	25.0	54.0	66.3	0.49	42.9
RECOVERY in the Tailings	6.69	0.61	16.2	28.2	0.07	13.0

a) While 21.4 % of the chalcopyrite in the feed occurs as free grains 54.4 % occurs as free plus sub-free grains. This relatively low fraction of 'recoverable' grains of chalcopyrite indicates low 'effective' liberation. The Cu-concentrate recovers 68.9 % of the free grains and 72.9 % of the sub-free grains, which accounts for 90 % of the chalcopyrite in the Cu-concentrate. The remainder of the 'recoverable' grains of chalcopyrite are recovered in the Zn-concentrate (i.e. 23.9 % of the free and 25.0 % of the sub-free), the tailings (i.e. 6.69 % of the free and 0.61 % of the sub-free), and the Pb-concentrate (i.e. 0.49 % of the free and 1.50 % of the sub-free). These high losses of 29 % of the 'recoverable' grains account for approximately 39, 32 and 12 % of the chalcopyrite in the Pb- and Zn-concentrates and tailings, respectively. Thus, the 'recoverable' grains that are not recovered in the Cu-concentrate, account for 15.7 % of the chalcopyrite in the feed, of which 13.5 % (i.e. 86 %) are recovered in the Zn-concentrate. These losses are independent of liberation, and are due to poor selective flotation.

b) A further 10.8 % of the chalcopyrite in the feed occurs as middling grains, which are largely recovered in the Zn-concentrate (i.e. 54.0 %), with only 25.3 % recovered in the Cu-concentrate. A further 4.59 % of the middling grains are recovered in the Pb-concentrate, whereas 16.2 % are rejected to the tailings. While 75 % of the middling grains are not recovered in the Cu-concentrate, these losses account for 8.1 % of the chalcopyrite in the feed. Regrinding a stream enriched in these grains is expected to yield minor improvement in Cu recovery (i.e. $\leq$ 8 %).

c) Sub-middling grains comprise 35.0 % of the chalcopyrite in the feed and are largely recovered in the Zn-concentrate (i.e. 66.3 %), with only 4.19 % recovered in the Cu-concentrate. The sub-middling grains recovered in the Zn-concentrate account for 23.5 % of the chalcopyrite in the feed, and 55 % of the chalcopyrite in the Zn-concentrate. A further 28.2 % of the sub-middling grains are recovered in the tailings, accounting for 9.71 % of the chalcopyrite in the feed, and 75 % of the chalcopyrite in the tailings. The combined loss of 94.5 % of the sub-middling grains to the Zn-concentrate and tailings, corresponding to 33.1 % of the chalcopyrite in the feed, is the largest fraction of lost chalcopyrite. These losses are only redressable by extremely fine regrinding.

d) The four principal fractions of chalcopyrite unrecovered to the Cu-concentrate are thus: (1) 'recoverable' grains recovered in the Zn-concentrate (13.5 % of the Cu in the feed), (2) middling grains recovered in the Zn-concentrate (5.9 % of the Cu in the feed), (3) sub-middling grains recovered in the Zn-concentrate (23.5 % of the Cu in the feed), and sub-middling grains rejected to the tailings (9.7 % of the Cu in the feed). The first fraction is independent of liberation, whereas the latter three fractions are liberation dependent, and along with the minor component of 'over-sized', 'recoverable' grains, are amenable to fine regrinding.

8. The classification of sphalerite in the feed, in terms of the liberation categories is 49.2 % free, 46.2 % sub-free, 3.51 % middling and 1.06 % sub-middling grains. This is shown in the table below, along with the recoveries of each category.

SPHALERITE	FREE	SUB-FREE	MIDDLING	SUB-MIDDLING	TOTAL DERIVED Zn ASSAY	Zn REC.
LIBERATION in the float feed	49.2	46.2	3.51	1.06	16.5	100.0
RECOVERY in the Cu-Conc.	0.31	0.90	1.90	2.12	13.9	0.65
RECOVERY in the Pb-Conc.	0.28	1.65	5.19	6.72	10.4	1.15
RECOVERY in the Zn-Conc.	98.1	96.6	59.9	15.9	53.4	95.0
RECOVERY in the Tailings	1.30	0.89	33.0	75.3	0.74	3.17

a) Although 49.2 % of the sphalerite in the feed occurs as free grains, 95.4 % occurs as free plus sub-free grains. This extremely high fraction of 'recoverable' grains of sphalerite indicates exceptionally high 'effective' liberation. Although 1.30 % of the free grains are rejected to the tailings and 1.65 % of the sub-free grains are recovered in the Pb-concentrate, 98.1 and 96.6 % of the free and sub-free grains, respectively are recovered in the Zn-concentrate. Thus, 97.7 % of the 'recoverable' grains of sphalerite are recovered in the Zn-concentrate, accounting for 93 % of the sphalerite in the feed, and 97 % of the sphalerite in the Zn-concentrate. The loss of 1.2 % of the 'recoverable' sphalerite to the tailings, accounting for 35 % of the sphalerite in the tailings, is the only significant fraction of 'recoverable' sphalerite not recovered in the Zn-concentrate.

b) Of the sphalerite in the feed, 3.51 % occurs as middling grains. These grains are principally recovered in the Zn-concentrate (i.e. 59.9 %), and account for 2.1 % of the sphalerite in the feed, and 2.2 % of the sphalerite in the Zn-concentrate. A further 1.90 % of the middling grains are recovered in the Cu-concentrate, 5.19 % in the Pb-concentrate, whereas 33.0 % are rejected to the tailings. This loss to the tailings accounts for 1.22 % of the sphalerite in the feed, yet approximately 39 % of the sphalerite in the tailings, and is the largest single fraction of sphalerite unrecovered to the Zn-concentrate. Although middling grains are readily amenable to regrinding, enhanced liberation and recovery by regrinding these grains is likely to be relatively insignificant (i.e. $\leq$ 1 %).

c) Of the 1.06 % sub-middling sphalerite grains in the feed only 15.9 % are recovered in the Zn-concentrate, 2.12 % in the Cu-concentrate, 6.72 % in the Pb-concentrate, whereas 75.3 % are rejected to the tailings. Sub-middling grains comprise 27 % of the sphalerite in the tailings, yet account for 0.84 % of the sphalerite in the feed. The combined loss of 84 % of the sub-middling grains, corresponding to approximately 1 % of the sphalerite in the feed, is unrecoverable without recourse to extremely fine regrinding. However, the potential increase in liberation and recovery arising from regrinding these grains is relatively insignificant (i.e. < 1 %).

d) The host particle size distributions of sphalerite in the five end products show that the sphalerite recovered in the Pb-concentrate and rejected to the tailings are coarser-grained than that recovered in the Zn- or Cu-concentrates. Host particle size analysis showed that the sphalerite 'slime' fraction is negligible in all products, and that 40 % of the sphalerite in tailings is 'over-sized', and thus lies beyond the optimum particle flotation limit of 100 um. However, petrographic evidence indicates that 'over-sized', 'recoverable' sphalerite constitute up to approximately 50 % of the sphalerite in the tailings. Thus, much of the losses of sphalerite in the

tailings, corresponding to the three largest fractions of lost sphalerite, are amenable to regrinding. The regrind can (1) reduce losses of 'over-sized', 'recoverable' grains, and (2) increase liberation from middling and sub-middling grains that are being rejected to the tailings.

e) The presence of trace amounts of the Zn-spinel gahnite (observed in the Stall Lake circuit products) was not confirmed during the study, and may contribute a significant fraction of the Zn assay in the tailings. Thus, the losses of Zn to the tailings, modelled in terms of the liberation categories of sphalerite, may be slightly less than indicated above.

9. The classification of galena in the feed, in terms of the liberation categories is 52.1 % free, 25.7 % sub-free, 9.41 % middling and 12.9 % sub-middling grains. This is shown in the table below, along with the recoveries of each category.

GALENA	FREE	SUB-FREE	MIDDLING	SUB-MIDDLING	TOTAL DERIVED Pb ASSAY	Pb REC.
LIBERATION in the float feed	52.1	25.7	9.41	12.9	0.71	100.0
RECOVERY in the Cu-Conc.	2.28	4.06	2.90	2.66	2.60	2.86
RECOVERY in the Pb-Conc.	92.1	58.3	39.6	30.8	27.1	70.5
RECOVERY in the Zn-Conc.	3.11	35.1	15.3	6.14	0.31	13.3
RECOVERY in the Tailings	2.57	2.60	42.1	60.4	0.15	13.4

a) Whereas 52.1 % of the galena feed occurs as free grains, 77.8 % occurs as free plus sub-free grains. This relatively high fraction of 'recoverable' grains of galena indicates moderately high 'effective' liberation. However, only 92.1 % of the free grains and 58.3 % of the sub-free grains are recovered in the Pb-concentrate. Combined this corresponds to 80.7 % recovery of the 'recoverable' grains, accounting for 62.8 % of the galena in the feed, and 89 % of the galena in the Pb-concentrate. The largest fraction of 'recoverable' galena not recovered in the Pb-concentrate (i.e. 14.1 %), is in the Zn-concentrate, and accounts for 11.0 % of the galena in the feed, and 83 % of the galena in the Zn-concentrate.

b) Of the galena in the feed, 9.41 % occurs as middling grains. These grains are principally rejected to the tailings (i.e. 42.1 %), whereas slightly less is recovered in the Pb-concentrate (i.e. 39.6 %). In addition, 2.90 and 15.3 % are recovered in the Cu- and Zn-concentrates, respectively. The loss of 42.1 % of the middling galena to the tailings, accounts for 3.86 % of galena in the feed, and 29 % of the galena in the tailings. This loss to the tailings is the third largest fraction of galena unrecovered to the Pb-concentrate. The middling grains lost to the Zn-concentrate and tailings combined account for 5.35 % of the galena in the feed and are amenable to regrinding. Enhanced liberation and recovery by regrinding these grains is expected to be relatively significant (i.e. ≤ 5 %).

c) Of the 12.9 % sub-middling galena grains in the feed, 30.8 % are recovered in the Pb-concentrate, 2.66 % in the Cu-concentrate, 6.14 % in the Zn-concentrate, whereas 60.4 % are rejected to the tailings. The latter sub-middling grains comprise 57 % of the galena in the tailings, account for 7.58 % of the galena in the feed, and constitute the second largest fraction of galena unrecovered to the Pb-concentrate. The combined loss of 69 % of the sub-middling grains, accounting for 8.7 % of the galena in the feed, is unrecoverable without recourse to extremely fine regrinding. The increase in liberation and recovery arising from regrinding these grains is expected to be relatively significant (i.e. ≤ 8 %).

d) Approximately 83 % of the galena losses to the Zn-concentrate occur as 'recoverable' grains, are independent of liberation, and occur in particles which are not 'over-sized', and are thus not amenable to regrinding. In contrast, approximately 85 % of the galena losses to the tailings occur as middling and sub-middling grains, are liberation dependent, and are thus amenable to fine regrinding.

10. Of the pyrite in the feed, 38.6 % occur as free grains, although another 58.4 % occur as sub-free grains, such that the 'effective' liberation of pyrite is 97.0 %. The rejection of 94.7 % of the free plus sub-free pyrite grains is largely responsible for the rejection of 94.6 % of the pyrite to the tailings. Nonetheless, free plus sub-free pyrite account for approximately 82, 95 and 81 % of the pyrite in the Cu-, Pb- and Zn-concentrates, respectively. Reducing the pyrite content of the concentrates, which decreases concentrate grades (i.e. 11.4 and 51.3 % pyrite in the Cu and Pb-concentrates, respectively), is thus largely independent of liberation.

11. Approximately 40 % of the chalcopyrite, 2.5 % of the sphalerite and 13 % of the galena in the feed are unrecovered to the respective concentrates, and occur as either (1) middling and sub-middling grains, or to a lesser extent (2) as 'over-sized', 'recoverable' grains. These grains are variably amenable to regrinding. In order for a single regrind to address each of these fractions, the

regrind mill must be placed near the head of the circuit. However, unless a stream in which all these fractions are preferentially concentrated can be selected, a finer primary grind may be preferred. The ore was only ground to 48.5 % - 325 mesh (i.e. 43 um). However, because the recovery of sphalerite is exceptionally high (i.e. 95 %), and is recovered in a high grade Zn-concentrate, remedial actions such as a lower primary grind or regrinding may not be economically justified by the extent of the Zn, Cu and Pb losses. The low Cu head grades, and the recovery (during Zn-refining) of the Cu lost to the Zn-concentrate (75 % of the lost Cu), probably negate remedial measures aimed principally at improving the Cu metallurgy.

12. The mineral quantities of electrum, tetrahedrite and pyrargyrite, and the Ag content of sphalerite, galena, pyrite and chalcopyrite were not determined. Thus, the principal mineralogical controls affecting the distribution of Au and Ag were not elucidated. Despite the high head grade of 2.52 ppm Au, only one grain of electrum was observed in the five products, suggesting a high 'invisible' Au content in the ore. Whereas only one grain of pyrargyrite was observed, abundant tetrahedrite was observed, particularly in the Cu-concentrate, suggesting that tetrahedrite is a major Ag-carrier. It is inferred that tetrahedrite, sphalerite, galena, pyrite and chalcopyrite are the principal Ag-carriers in the ore.

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Appendix A

RAW MINERAL QUANTITIES DATA

TABLE 1

MINERAL QUANTITIES OF THE MINERALS OF INTEREST IN THE FIVE CHISEL LAKE END PRODUCTS.

PRODUCT	Gangue	Pyrite	Pyrr.	Cpy.	Sphal.	Asp.	Gal.
	Surface area (1,000 um^2)						
Feed	1500.	1610.	51.5	39.7	1290.	11.7	23.3
Cu-Conc.	186.	176.	13.8	796.	346.	4.23	22.5
Pb-Conc.	247.	2230.	67.5	24.8	547.	115.	1110.
Zn-Conc.	186.	79.7	18.4	42.5	1940.	0.74	6.61
Tails.	2050.	2770.	44.1	5.53	29.0	19.5	3.25

Appendix B

GRAIN SIZE AND CLASSIFICATION TABLES FOR CHALCOPYRITE, SPHALERITE, GALENA AND PYRITE

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.7	52.7
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	474.	474.
6.69	0.00	0.00	21.8	34.5	10.9	0.00	72.7	0.00	23.6	0.00	932.	.110E+04
9.45	0.00	14.5	149.	49.1	83.6	0.00	32.7	56.3	61.8	0.00	.157E+04	.202E+04
13.3	50.9	198.	67.2	0.00	63.6	83.0	65.4	113.	225.	396.	.284E+04	.331E+04
18.9	376.	540.	43.6	127.	0.00	451.	136.	144.	392.	.119E+04	.332E+04	.672E+04
26.6	525.	229.	99.9	0.00	218.	0.00	0.00	298.	885.	.179E+04	.408E+04	.885E+04
37.7	919.	448.	0.00	0.00	0.00	0.00	0.00	663.	869.	.419E+04	.412E+04	.112E+05
53.2	752.	0.00	0.00	0.00	0.00	0.00	692.	0.00	0.00	.199E+04	.164E+04	.527E+04
75.2	929.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	929.
106.	594.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	594.
150.	12.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.7
212.	12.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.7
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.417E+04	.142E+04	382.	211.	376.	540.	.128E+04	.127E+04	.238E+04	.956E+04	.182E+05	.397E+05

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.133	.133
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	1.19
6.69	0.00	0.00	.549E-01	.869E-01	.274E-01	0.00	.183	0.00	.594E-01	0.00	2.35	2.76
9.45	0.00	.366E-01	.375	.123	.210	0.00	.823E-01	.142	.155	0.00	3.95	5.00
13.3	.128	.498	.169	0.00	.160	.224	.165	.283	.567	.997	5.13	8.32
18.9	.946	1.36	.110	.320	0.00	1.13	.343	.361	.988	3.00	8.35	16.9
26.6	1.32	.576	.251	0.00	.549	0.00	0.00	.750	2.03	4.50	10.3	20.2
37.7	2.31	1.11	0.00	0.00	0.00	0.00	0.00	1.67	2.19	10.5	10.4	28.2
53.2	1.89	0.00	0.00	0.00	0.00	0.00	2.24	0.00	0.00	5.01	4.12	13.3
75.2	2.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.34
106.	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50
150.	.320E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.320E-01
212.	.320E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.320E-01
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.5	3.58	.960	.530	.946	1.36	3.02	3.21	5.98	24.1	45.9	100.

TABLE 1.

Data for the classification and size distribution of free and unliberated CHALCOPYRITE in the feed. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	336.	336.
4.73	0.00	0.00	0.00	0.00	9.09	0.00	25.4	0.00	0.00	0.00	.848E+04	.852E+04
6.69	0.00	0.00	0.00	27.3	14.5	14.5	173.	169.	96.3	109.	.183E+05	.183E+05
9.45	0.00	9.09	49.1	65.4	231.	331.	412.	422.	531.	278.	.390E+05	.414E+05
13.3	0.00	165.	61.8	149.	256.	469.	323.	.118E+04	.183E+04	.147E+04	.624E+05	.684E+05
18.9	34.5	63.6	402.	278.	716.	618.	761.	.149E+04	.581E+04	.185E+05	.954E+05	.116E+06
26.6	133.	721.	571.	651.	732.	692.	.174E+04	.467E+04	.635E+04	.266E+05	.146E+06	.189E+06
37.7	382.	411.	0.00	.128E+04	596.	660.	522.	.366E+04	.154E+05	.749E+05	.143E+06	.241E+06
53.2	556.	825.	467.	0.00	.150E+04	767.	.448E+04	.841E+04	.226E+05	.184E+06	.128E+06	.271E+06
75.2	690.	869.	0.00	0.00	.135E+04	.195E+04	.217E+04	.545E+04	.227E+05	.117E+06	.676E+05	.220E+06
106.	0.00	0.00	.162E+04	0.00	0.00	0.00	0.00	0.00	.685E+04	.450E+05	.192E+05	.726E+05
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.271E+05	0.00	.271E+05
212.	0.00	0.00	0.00	0.00	0.00	0.00	.144E+05	0.00	0.00	0.00	0.00	.144E+05
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.169E+04	.308E+04	.317E+04	.237E+04	.541E+04	.552E+04	.258E+05	.254E+05	.821E+05	.407E+06	.728E+06	.129E+07

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.261E-01	.261E-01
4.73	0.00	0.00	0.00	0.00	.705E-03	0.00	.197E-02	0.00	0.00	0.00	.658	.661
6.69	0.00	0.00	0.00	.212E-02	.113E-02	.113E-02	.134E-01	.131E-01	.747E-02	.846E-02	1.42	1.47
9.45	0.00	.705E-03	.381E-02	.508E-02	.179E-01	.257E-01	.328E-01	.327E-01	.412E-01	.216E-01	3.03	3.21
13.3	0.00	.128E-01	.479E-02	.116E-01	.193E-01	.379E-01	.251E-01	.919E-01	.142	.114	4.85	5.31
18.9	.733E-02	.494E-02	.312E-01	.216E-01	.556E-01	.479E-01	.591E-01	.115	.451	.817	7.40	9.01
26.6	.103E-01	.560E-01	.443E-01	.505E-01	.568E-01	.537E-01	.135	.363	.493	2.06	11.4	14.7
37.7	.234E-01	.319E-01	0.00	.931E-01	.463E-01	.512E-01	.405E-01	.284	1.19	5.81	11.1	18.7
53.2	.433E-01	.640E-01	.362E-01	0.00	.116	.595E-01	.348	.653	1.76	8.05	9.93	21.0
75.2	.465E-01	.627E-01	0.00	0.00	.105	.151	.168	.423	1.76	9.00	5.24	17.0
106.	0.00	0.00	.125	0.00	0.00	0.00	0.00	0.00	.532	3.49	1.49	5.64
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	0.00	2.10
212.	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.00	0.00	0.00	0.00	1.12
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.131	.233	.246	.184	.420	.428	1.94	1.97	6.37	31.6	56.5	100.

TABLE 2.

Data for the classification and size distribution of free and unliberated SPHALERITE in the feed. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	472.	472.
3.35												
3.63	1.82	0.00	7.27	7.27	0.00	0.00	0.00	0.00	0.00	0.00	903.	923.
4.73												
10.9	16.4	63.6	56.3	14.5	0.00	0.00	0.00	0.00	0.00	0.00	.133E+04	.149E+04
6.69												
47.2	45.4	45.4	0.00	56.3	70.9	36.3	38.2	0.00	0.00	0.00	.203E+04	.237E+04
9.45												
70.9	40.0	171.	30.9	0.00	158.	83.6	0.00	0.00	0.00	0.00	.211E+04	.266E+04
13.3												
233.	196.	316.	133.	76.3	94.5	225.	0.00	721.	218.	0.00	.243E+04	.465E+04
18.9												
289.	144.	0.00	0.00	214.	0.00	0.00	376.	0.00	0.00	.103E+04	.210E+04	.416E+04
26.6												
425.	116.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.130E+04	.184E+04
37.7												
511.	698.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.125E+04	0.00	0.00	.246E+04
53.2												
458.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	458.
75.2												
204.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	204.
106.												
118.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	118.
150.												
9.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.09
212.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.238E+04	.126E+04	596.	227.	369.	323.	345.	414.	.197E+04	.125E+04	.127E+05	.218E+05	

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.17	2.17
3.35												
.167E-01	.833E-02	0.00	.333E-01	.333E-01	0.00	0.00	0.00	0.00	0.00	0.00	4.14	4.23
4.73												
.500E-01	.750E-01	.292	.258	.667E-01	0.00	0.00	0.00	0.00	0.00	0.00	6.11	6.85
6.69												
.217	.208	.208	0.00	.258	.325	.167	.175	0.00	0.00	0.00	9.29	10.8
9.45												
.325	.183	.783	.142	0.00	.725	.383	0.00	0.00	0.00	0.00	9.67	12.2
13.3												
1.07	.900	1.45	.608	.350	.433	1.03	0.00	3.31	1.000	0.00	11.2	21.3
18.9												
1.32	.658	0.00	0.00	.983	0.00	0.00	1.72	0.00	4.72	0.00	9.65	19.1
26.6												
1.95	.533	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.97	8.46
37.7												
2.34	3.20	0.00	0.00	0.00	0.00	0.00	0.00	5.72	0.00	0.00	0.00	11.3
53.2												
2.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10
75.2												
.933	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.933
106.												
.542	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.542
150.												
.417E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.417E-01
212.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.9	5.77	2.73	1.04	1.69	1.48	1.58	1.90	5.03	5.72	58.1	100.	

TABLE 3.

Data for the classification and size distribution of free and unliberated GALENA in the feed. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	3.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	243.	243.
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.2	.714E+04	.718E+04
6.69	0.00	0.00	0.00	45.4	142.	98.1	118.	49.1	36.3	78.1	.176E+05	.182E+05
9.45	0.00	12.7	165.	414.	407.	747.	374.	641.	243.	124.	.317E+05	.348E+05
13.3	50.9	256.	263.	267.	532.	725.	.180E+04	.365E+04	.392E+04	.127E+04	.550E+05	.678E+05
18.9	169.	563.	478.	627.	783.	.116E+04	.160E+04	.566E+04	.993E+04	.128E+05	.815E+05	.115E+06
26.6	376.	322.	754.	903.	996.	.311E+04	.430E+04	.108E+05	.256E+05	.425E+05	.111E+06	.201E+06
37.7	371.	572.	236.	263.	374.	.275E+04	.108E+05	.212E+05	.473E+05	.114E+06	.910E+05	.289E+06
53.2	.117E+04	721.	356.	.130E+04	.180E+04	.577E+04	.939E+04	.211E+05	.793E+05	.164E+06	.696E+05	.355E+06
75.2	320.	620.	823.	.249E+04	.149E+04	.349E+04	.202E+04	.107E+05	.563E+05	.224E+06	.222E+05	.324E+06
106.	812.	0.00	0.00	0.00	0.00	0.00	0.00	.160E+05	.438E+05	.960E+05	.207E+05	.177E+06
150.	316.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.238E+05	0.00	.241E+05
212.	.111E+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.111E+04
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.470E+04	.307E+04	.308E+04	.631E+04	.658E+04	.179E+05	.304E+05	.897E+05	.266E+06	.679E+06	.508E+06	.161E+07

B.

	3.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.151E-01	.151E-01
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.236E-02	.442	.445
6.69	0.00	0.00	0.00	.281E-02	.678E-02	.600E-02	.731E-02	.304E-02	.225E-02	.484E-02	1.09	1.13
9.45	0.00	.788E-03	.102E-01	.257E-01	.252E-01	.463E-01	.232E-01	.397E-01	.151E-01	.765E-02	1.96	2.15
13.3	.315E-02	.153E-01	.163E-01	.165E-01	.367E-01	.449E-01	.111	.226	.243	.785E-01	3.41	4.20
18.9	.105E-01	.349E-01	.296E-01	.388E-01	.485E-01	.719E-01	.988E-01	.351	.615	.790	5.04	7.13
26.6	.233E-01	.139E-01	.467E-01	.559E-01	.617E-01	.193	.266	.669	1.58	2.63	6.88	12.4
37.7	.230E-01	.354E-01	.146E-01	.163E-01	.232E-01	.170	.671	1.31	2.93	7.06	5.64	17.9
53.2	.725E-01	.447E-01	.221E-01	.806E-01	.111	.357	.581	1.30	4.91	10.2	4.31	22.0
75.2	.198E-01	.384E-01	.510E-01	.154	.924E-01	.216	.125	.661	3.49	13.9	1.38	20.1
106.	.503E-01	0.00	0.00	0.00	0.00	0.00	0.00	.989	2.71	5.95	1.26	11.0
150.	.196E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.00	1.49
212.	.689E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.689E-01
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.291	.190	.191	.391	.488	1.11	1.86	5.55	16.5	42.0	31.4	100.

TABLE 4.

Data for the classification and size distribution of free and unliberated PYRITE in the feed. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	5.12	0.00	0.00	0.00	0.00	.109E+04	.110E+04
3.35											
0.00	0.00	0.00	12.3	23.6	8.19	34.8	0.00	0.00	0.00	.330E+04	.338E+04
4.73											
0.00	6.14	57.4	141.	155.	264.	244.	100.	92.2	70.7	.587E+04	.701E+04
6.69											
14.3	126.	109.	250.	271.	420.	423.	.185E+04	.109E+04	267.	.929E+04	.133E+05
9.45											
153.	296.	540.	439.	400.	577.	791.	.157E+04	.268E+04	.212E+04	.120E+05	.216E+05
13.3											
370.	975.	621.	522.	352.	.177E+04	.155E+04	.237E+04	.373E+04	.99AE+04	.235E+05	.457E+05
18.9											
920.	.150E+04	.171E+04	.200E+04	.180E+04	.120E+04	.138E+04	.390E+04	.854E+04	.331E+05	.325E+05	.886E+05
26.6											
.134E+04	.185E+04	.188E+04	.389E+04	.684E+04	.379E+04	.119E+04	.406E+04	.771E+04	.592E+05	.346E+05	.126E+06
37.7											
.257E+04	.193E+04	.197E+04	.160E+04	.400E+04	.347E+04	.514E+04	.543E+04	.161E+05	.883E+05	.467E+05	.177E+06
53.2											
.101E+04	508.	.242E+04	933.	.147E+04	0.00	0.00	.738E+04	.179E+05	.154E+06	.270E+05	.212E+06
75.2											
0.00	.144E+04	.124E+04	0.00	0.00	0.00	.438E+04	0.00	.545E+04	.626E+05	0.00	.750E+05
106.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.639E+04	.863E+04	.106E+05	.980E+04	.146E+05	.115E+05	.151E+05	.258E+05	.633E+05	.409E+06	.156E+06	.771E+06

B.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	.665E-03	0.00	0.00	0.00	0.00	.142	.142
3.35											
0.00	0.00	0.00	.159E-02	.306E-02	.106E-02	.452E-02	0.00	0.00	0.00	.428	.439
4.73											
0.00	.797E-03	.744E-02	.183E-01	.201E-01	.343E-01	.316E-01	.148E-01	.120E-01	.917E-02	.761	.909
6.69											
.186E-02	.163E-01	.141E-01	.335E-01	.352E-01	.556E-01	.549E-01	.136	.142	.347E-01	1.21	1.73
9.45											
.198E-01	.384E-01	.700E-01	.570E-01	.623E-01	.748E-01	.103	.284	.348	.275	1.55	2.81
13.3											
.498E-01	.127	.805E-01	.678E-01	.457E-01	.230	.201	.386	.484	1.28	3.05	5.92
18.9											
.119	.195	.222	.259	.234	.156	.178	.586	1.11	4.29	4.22	11.5
26.6											
.173	.248	.245	.585	.784	.491	.155	.527	1.00	7.68	4.49	16.3
37.7											
.334	.249	.255	.200	.519	.451	.667	.784	2.10	11.5	6.00	23.0
53.2											
.132	.659E-01	.315	.121	.191	0.00	0.00	.947	2.32	19.9	3.50	27.5
75.2											
0.00	.187	.161	0.00	0.00	0.00	.558	0.00	.787	8.12	0.00	9.74
106.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.829	1.12	1.37	1.27	1.89	1.49	1.95	3.35	8.22	53.1	25.4	100.

TABLE 5.

Data for the classification and size distribution of free and unliberated CHALCOPYRITE in the Cu-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	448.	448.
3.35												
0.00	0.00	0.00	0.00	6.14	19.5	30.9	0.00	0.00	0.00	0.00	.148E+04	.154E+04
4.73												
0.00	7.17	32.8	69.6	87.1	132.	125.	116.	27.7	0.00	.255E+04	.311E+04	
6.69												
6.14	89.1	52.2	0.00	42.0	346.	247.	620.	360.	226.	.386E+04	.587E+04	
9.45												
76.8	127.	100.	202.	185.	616.	725.	.104E+04	.114E+04	.183E+04	.613E+04	.123E+05	
13.3												
123.	327.	425.	679.	983.	843.	681.	.117E+04	.389E+04	.482E+04	.945E+04	.228E+05	
18.9												
364.	419.	341.	.112E+04	510.	544.	976.	.411E+04	.921E+04	.171E+05	.167E+05	.514E+05	
26.6												
605.	120.	.109E+04	296.	.383E+04	.221E+04	.449E+04	.321E+04	.473E+04	.310E+05	.730E+04	.581E+05	
37.7												
694.	.174E+04	924.	726.	.277E+04	.333E+04	.169E+04	.457E+04	.857E+04	.532E+05	.173E+05	.955E+05	
53.2												
.112E+04	.185E+04	812.	0.00	0.00	0.00	.217E+04	.256E+04	0.00	.411E+05	.742E+04	.562E+05	
75.2												
120.	0.00	0.00	.251E+04	0.00	0.00	0.00	.483E+04	0.00	0.00	0.00	.746E+04	
106.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
150.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
212.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
.312E+04	.388E+04	.387E+04	.564E+04	.763E+04	.783E+04	.111E+05	.228E+05	.279E+05	.145E+06	.723E+05	.315E+06	

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.142	.142	
3.35												
0.00	0.00	0.00	.195E-02	.618E-02	.124E-01	0.00	0.00	0.00	0.00	.469	.469	
4.73												
0.00	.228E-02	.104E-01	.221E-01	.277E-01	.325E-01	.397E-01	.360E-01	.870E-02	0.00	.889	.989	
6.69												
.195E-02	.203E-01	.166E-01	0.00	.133E-01	.110	.704E-01	.199	.117	.719E-01	1.23	1.86	
9.45												
.244E-01	.403E-01	.593E-01	.641E-01	.569E-01	.196	.230	.330	.361	.581	1.95	3.89	
13.3												
.390E-01	.104	.135	.216	.312	.204	.216	.373	1.23	1.53	2.88	7.24	
18.9												
.115	.133	.108	.355	.162	.173	.310	1.38	2.92	5.43	5.32	16.3	
26.6												
.192	.381E-01	.347	.940E-01	.964	.702	1.43	1.02	1.50	9.84	2.34	18.5	
37.7												
.221	.554	.293	.231	.878	1.06	.536	1.45	2.72	16.9	5.49	30.3	
53.2												
.357	.334	.258	0.00	0.00	0.00	.688	.814	0.00	13.1	2.36	17.9	
75.2												
.407E-01	0.00	0.00	.796	0.00	0.00	0.00	1.53	0.00	0.00	0.00	2.37	
106.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
150.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
212.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
.991	1.23	1.23	1.78	2.42	2.49	3.53	7.07	8.07	47.4	23.0	100.	

TABLE 6.

Data for the classification and size distribution of free and unliberated SPHALERITE in the Cu-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	533.	533.
3.35											
1.02	0.00	5.12	0.00	6.14	0.00	0.00	0.00	0.00	0.00	747.	759.
4.73											
11.3	0.00	20.5	12.3	10.2	0.00	23.6	29.7	0.00	0.00	992.	.116E+04
6.69											
20.5	13.3	24.6	0.00	43.0	0.00	0.00	0.00	68.6	0.00	955.	.112E+04
9.45											
18.4	76.8	53.3	51.2	0.00	0.00	73.7	0.00	184.	0.00	.144E+04	.161E+04
13.3											
86.0	125.	163.	184.	0.00	425.	189.	468.	238.	164.	.121E+04	.388E+04
18.9											
156.	231.	168.	132.	0.00	0.00	660.	0.00	0.00	981.	.135E+04	.367E+04
26.6											
274.	359.	441.	0.00	0.00	439.	0.00	592.	0.00	953.	.182E+04	.494E+04
37.7											
66.6	0.00	0.00	0.00	0.00	0.00	0.00	.110E+04	0.00	0.00	0.00	.117E+04
53.2											
202.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.327E+04	0.00	.347E+04
75.2											
105.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	105.
106.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
941.	806.	669.	380.	59.4	924.	865.	.219E+04	484.	.537E+04	.904E+04	.218E+05

B.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.45	2.45
3.35											
.470E-02	0.00	.235E-01	0.00	.282E-01	0.00	0.00	0.00	0.00	0.00	3.43	3.49
4.73											
.518E-01	0.00	.941E-01	.565E-01	.470E-01	0.00	.106	.136	0.00	0.00	4.56	5.05
6.69											
.941E-01	.612E-01	.113	0.00	.136	0.00	0.00	0.00	.315	0.00	4.39	5.17
9.45											
.847E-01	.353	.245	.235	0.00	0.00	.339	0.00	.480	0.00	6.60	8.34
13.3											
.395	.574	.748	.480	0.00	1.95	.439	2.15	1.06	.753	5.55	14.2
18.9											
.715	1.06	.743	.697	0.00	0.00	3.83	0.00	0.00	4.51	6.18	16.8
26.6											
1.26	1.65	2.03	0.00	0.00	2.29	0.00	2.72	0.00	4.36	8.37	22.7
37.7											
.306	0.00	0.00	0.00	0.00	0.00	0.00	5.07	0.00	0.00	0.00	5.37
53.2											
.327	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.0	0.00	15.3
75.2											
.485	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.485
106.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.32	3.70	3.93	1.38	.273	4.24	3.98	10.1	1.65	24.7	41.5	100.

TABLE 7.

Data for the classification and size distribution of free and unliberated GALENA in the Cu-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	3.97	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	203.	203.
4.73	0.00	0.00	0.00	0.00	0.19	11.3	0.00	0.00	0.00	0.00	557.	577.
6.69	0.00	5.12	44.0	44.0	26.6	78.3	56.3	20.5	0.00	0.00	789.	.1000E+04
9.45	0.00	73.7	134.	62.5	83.0	253.	120.	483.	0.00	0.00	.1456E+04	.2586E+04
13.3	76.0	61.4	173.	176.	86.0	236.	261.	386.	190.	312.	.2411E+04	.4378E+04
18.9	225.	150.	0.00	124.	117.	658.	154.	883.	.1338E+04	.1818E+04	.3688E+04	.9338E+04
26.6	315.	74.8	460.	228.	740.	828.	857.	860.	.2378E+04	.6178E+04	.8958E+04	.2188E+05
37.7	725.	337.	899.	0.00	.1068E+04	.2838E+04	.1458E+04	.4578E+04	.2588E+04	.2238E+05	.1558E+05	.5148E+05
53.2	494.	630.	972.	.2238E+04	.4858E+04	0.00	.1128E+04	.1428E+04	.8778E+04	.2328E+05	.3848E+04	.4708E+05
75.2	37.3	0.00	0.00	.1978E+04	.1368E+04	0.00	.4078E+04	0.00	0.00	.1388E+05	.3118E+04	.2278E+05
106.	278.	928.	0.00	0.00	0.00	0.00	0.00	.5678E+04	0.00	0.00	0.00	.6888E+04
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.2218E+04	.2268E+04	.2668E+04	.3938E+04	.7738E+04	.4118E+04	.8188E+04	.1428E+05	.1508E+05	.6488E+05	.4878E+05	.1688E+06

B.

	3.97	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.121	.121
4.73	0.00	0.00	0.00	0.00	.4887-02	.671E-02	0.00	0.00	0.00	0.00	.332	.343
6.69	0.00	.305E-02	.262E-01	.262E-01	.159E-01	.573E-01	.335E-01	.122E-01	0.00	0.00	.470	.644
9.45	0.00	.439E-01	.799E-01	.372E-01	.494E-01	.151	.713E-01	.243	0.00	0.00	.863	1.54
13.3	.457E-01	.366E-01	.103	.105	.512E-01	.140	.167	.230	.113	.186	1.43	2.61
18.9	.134	.830E-01	0.00	.738E-01	.695E-01	.391	.915E-01	.526	.798	1.80	2.31	5.56
26.6	.186	.445E-01	.274	.136	.441	.493	.510	.488	1.42	3.67	5.34	13.0
37.7	.432	.201	.535	0.00	.630	1.21	.865	2.72	1.49	13.3	9.25	30.6
53.2	.294	.375	.579	1.33	2.53	0.00	.669	.860	5.22	13.8	2.29	28.0
75.2	.579E-01	0.00	0.00	.634	.809	0.00	2.42	0.00	0.00	7.74	1.85	13.5
106.	.165	.552	0.00	0.00	0.00	0.00	0.00	3.38	0.00	0.00	0.00	4.10
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.32	1.35	1.60	2.34	4.68	2.45	4.83	8.45	9.03	39.8	24.3	100.

TABLE 8.

Data for the classification and size distribution of free and unliberated PYRITE in the Cu-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	283.	283.
4.73	0.00	0.00	0.00	0.00	6.14	18.4	9.22	15.4	0.00	0.00	460.	509.
6.69	0.00	0.00	27.7	17.4	46.1	31.0	103.	19.5	0.00	30.7	393.	674.
9.45	0.00	25.6	45.1	92.2	21.5	57.4	0.00	108.	199.	49.2	313.	910.
13.3	42.0	50.2	56.3	143.	230.	356.	0.00	86.0	98.3	135.	0.00	.120E+04
18.9	176.	88.5	161.	0.00	129.	195.	144.	441.	296.	186.	190.	.185E+04
26.6	473.	426.	296.	113.	0.00	271.	315.	348.	0.00	397.	0.00	.264E+04
37.7	781.	360.	252.	0.00	326.	0.00	0.00	784.	0.00	0.00	0.00	.246E+04
53.3	.113E+04	0.00	238.	0.00	593.	.111E+04	0.00	0.00	0.00	0.00	0.00	.313E+04
75.8	.159E+04	0.00	0.00	0.00	.363E+04	0.00	0.00	0.00	0.00	.467E+04	0.00	.103E+05
106.	373.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	373.
150.	483.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	483.
818.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.505E+04	687.	.116E+04	366.	.818E+04	.190E+04	572.	.172E+04	593.	.567E+04	.164E+04	.248E+05

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14	1.14
4.73	0.00	0.00	0.00	0.00	.246E-01	.743E-01	.371E-01	.619E-01	0.00	0.00	1.85	2.05
6.69	0.00	0.00	.111	.702E-01	.194	.136	.417	.784E-01	0.00	.124	1.58	2.72
9.45	0.00	.163	.162	.371	.867E-01	.231	0.00	.433	.801	.198	1.26	3.67
13.3	.189	.262	.227	.578	.929	1.44	0.00	.347	.396	.545	0.00	4.83
18.9	.782	.908E-01	.648	0.00	.520	.425	.582	1.78	1.19	.751	.768	7.46
26.6	1.91	1.73	1.19	.454	0.00	1.07	1.27	1.40	0.00	1.68	0.00	10.6
37.7	3.15	1.45	1.16	0.00	1.31	0.00	0.00	2.84	0.00	0.00	0.00	9.93
53.3	4.96	0.00	1.09	0.00	2.39	4.49	0.00	0.00	0.00	0.00	0.00	12.6
75.8	6.41	0.00	0.00	0.00	15.4	0.00	0.00	0.00	0.00	19.6	0.00	41.5
106.	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50
150.	1.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.95
818.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	20.3	3.97	4.74	1.47	29.9	7.00	2.31	6.94	2.39	22.9	6.61	100.

TABLE 9.

Data for the classification and size distribution of free and unliberated CHALCOPYRITE in the Pb-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.14	9.22	.139E+04	.148E+04
3.35											
0.00	0.00	0.00	20.5	0.00	28.7	29.7	12.3	0.00	57.4	.301E+04	.336E+04
4.73											
0.00	0.00	7.17	31.7	81.9	14.3	23.6	149.	137.	141.	.533E+04	.537E+04
6.69											
0.00	70.7	125.	96.3	37.9	0.00	178.	97.3	197.	467.	.733E+04	.868E+04
9.45											
77.8	206.	436.	866.	831.	819.	737.	444.	544.	760.	.104E+05	.161E+05
13.3											
232.	356.	665.	.105E+04	896.	.231E+04	.163E+04	.510E+04	.322E+04	.331E+04	.130E+05	.318E+05
18.9											
376.	434.	.165E+04	.128E+04	.186E+04	.321E+04	.476E+04	.848E+04	.977E+04	.513E+04	.118E+05	.488E+05
26.6											
799.	819.	.244E+04	.256E+04	.337E+04	.719E+04	.803E+04	.131E+05	.235E+05	.261E+05	.638E+04	.943E+05
37.7											
.130E+04	.312E+04	.455E+04	.372E+04	.359E+04	.727E+04	.543E+04	.138E+05	.349E+05	.348E+05	.599E+04	.118E+06
53.2											
.215E+04	.423E+04	834.	0.00	.157E+04	0.00	.560E+04	.195E+05	.289E+05	.408E+05	0.00	.104E+06
75.2											
.229E+04	.116E+04	.572E+04	.273E+04	0.00	.531E+04	.993E+04	.626E+04	.167E+05	.363E+05	0.00	.864E+05
106.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.150E+05	.126E+05	0.00	.277E+05
150.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.722E+04	.184E+05	.164E+05	.124E+05	.122E+05	.262E+05	.364E+05	.669E+05	.133E+06	.161E+06	.655E+05	.547E+06

B.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.112E-02	.169E-02	.254	.257
3.35											
0.00	0.00	0.00	.374E-02	0.00	.524E-02	.543E-02	.225E-02	0.00	.105E-01	.697	.724
4.73											
0.00	0.00	.131E-02	.508E-02	.150E-01	.262E-02	.431E-02	.271E-01	.251E-01	.258E-01	.985	1.09
6.69											
0.00	.129E-01	.228E-01	.176E-01	.693E-02	0.00	.326E-01	.178E-01	.359E-01	.854E-01	1.34	1.57
9.45											
.142E-01	.376E-01	.798E-01	.158	.152	.150	.135	.813E-01	.994E-01	.139	1.91	2.95
13.3											
.425E-01	.652E-01	.122	.192	.164	.422	.298	.933	.589	.606	2.38	5.81
18.9											
.687E-01	.794E-01	.302	.234	.340	.587	.871	1.55	1.79	.938	2.16	8.91
26.6											
.146	.150	.446	.468	.616	1.32	1.47	2.40	4.29	4.78	1.17	17.2
37.7											
.237	.570	.831	.681	.656	1.33	.993	2.52	6.38	6.36	1.10	21.7
53.2											
.393	.773	.152	0.00	.288	0.00	1.82	3.56	5.28	7.46	0.00	18.9
75.2											
.418	.212	1.85	.588	0.00	.971	1.81	1.15	3.85	6.64	0.00	15.8
106.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.75	2.30	0.00	5.06
150.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.32	1.90	3.00	2.86	2.24	4.78	6.65	12.2	24.3	29.3	12.0	100.

TABLE 10.

Data for the classification and size distribution of free and unliberated SPHALERITE in the Pb-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	4.10	4.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.184E+05	.184E+05
3.35											
44.0	66.0	74.0	102.	59.0	42.0	0.00	0.00	0.00	0.00	0.00	0.00
4.73											
46.1	115.	134.	203.	187.	320.	103.	112.	101.	0.00	.349E+05	.355E+05
6.69											
209.	209.	253.	359.	292.	457.	474.	860.	531.	73.7	.439E+05	.470E+05
9.45											
320.	484.	418.	512.	975.	.103E+04	383.	.106E+04	.188E+04	945.	.537E+05	.67+E+05
13.3											
.184E+04	.131E+04	.138E+04	736.	736.	.121E+04	.133E+04	.192E+04	.240E+04	.557E+04	.881E+05	.977E+05
18.9											
.194E+04	.128E+04	.228E+04	.237E+04	.378E+04	.135E+04	.178E+04	.484E+04	.256E+04	.799E+04	.941E+05	.124E+06
26.6											
.434E+04	.294E+04	.418E+04	.266E+04	.289E+04	.101E+04	869.	.508E+04	.362E+04	.227E+05	.111E+06	.162E+06
37.7											
.475E+04	.478E+04	.385E+04	.123E+04	.552E+04	.173E+04	.256E+04	0.00	.223E+04	.319E+05	.121E+06	.178E+06
53.2											
.496E+04	.371E+04	.399E+04	.154E+04	.219E+04	.457E+04	.518E+04	.435E+04	.754E+04	.638E+05	.498E+05	.151E+06
75.2											
.353E+04	.436E+04	0.00	.887E+04	.390E+04	0.00	.553E+04	.689E+04	0.00	.499E+05	.307E+05	.113E+06
106.											
818.	.270E+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.126E+05	.172E+05	.333E+05
150.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.416E+05	0.00	.416E+05
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.228E+05	.219E+05	.164E+05	.186E+05	.209E+05	.117E+05	.181E+05	.241E+05	.211E+05	.235E+06	.684E+06	.109E+07

B.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	.375E-03	.375E-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.68	1.68
3.35											
.403E-02	.609E-02	.684E-02	.936E-02	.543E-02	.384E-02	0.00	0.00	0.00	0.00	2.27	2.30
4.73											
.421E-02	.105E-01	.123E-01	.185E-01	.171E-01	.300E-01	.946E-02	.102E-01	.927E-02	0.00	3.13	3.25
6.69											
.191E-01	.191E-01	.231E-01	.329E-01	.267E-01	.418E-01	.434E-01	.794E-01	.759E-01	.674E-02	3.93	4.38
9.45											
.292E-01	.369E-01	.382E-01	.468E-01	.891E-01	.938E-01	.277E-01	.971E-01	.164	.864E-01	5.45	6.16
13.3											
.949E-01	.120	.119	.675E-01	.673E-01	.111	.122	.176	.220	.509	7.33	8.93
18.9											
.177	.117	.201	.217	.345	.124	.155	.424	.234	.731	6.61	11.3
26.6											
.396	.269	.382	.243	.265	.920E-01	.813E-01	.464	.331	2.88	10.2	14.8
37.7											
.434	.437	.358	.113	.504	.158	.234	0.00	.284	2.63	11.1	16.3
53.2											
.453	.339	.365	.141	.200	.418	.474	.398	.698	5.76	4.53	13.8
75.2											
.323	.399	0.00	.811	.356	0.00	.585	.557	0.00	4.57	2.88	10.3
106.											
.748E-01	.247	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15	1.57	3.04
150.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	3.00
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.01	2.00	1.50	1.70	1.68	1.07	1.65	2.21	1.93	21.5	62.5	100.0

TABLE 11.

Data for the classification and size distribution of free and unliberated GALENA in the Pb-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	3.07	0.00	0.00	0.00	7.17	0.00	0.00	.116E+04	.117E+04
4.73	0.00	0.00	0.00	13.3	69.1	115.	136.	89.7	52.2	16.4	.482E+04	.447E+04
6.69	0.00	13.3	98.3	138.	163.	248.	632.	560.	219.	119.	.812E+04	.103E+05
9.45	0.00	74.8	147.	225.	265.	334.	.116E+04	.117E+04	.280E+04	.181E+04	.140E+05	.211E+05
13.3	77.8	53.3	98.3	170.	597.	985.	.143E+04	.254E+04	.613E+04	.989E+04	.320E+05	.540E+05
18.9	179.	234.	757.	333.	826.	.106E+04	.300E+04	.465E+04	.113E+05	.419E+05	.517E+05	.116E+06
26.6	359.	566.	786.	561.	.223E+04	.440E+04	.478E+04	.726E+04	.289E+05	.115E+06	.769E+05	.234E+06
37.7	345.	985.	653.	.190E+04	.445E+04	.293E+04	.536E+04	.112E+05	.378E+05	.277E+06	.897E+05	.433E+06
53.2	523.	258.	.284E+04	.184E+04	.413E+04	.924E+04	.674E+04	.189E+05	.268E+05	.398E+06	.701E+05	.539E+06
75.2	.104E+04	.182E+04	.225E+04	.582E+04	.164E+04	.458E+04	.743E+04	.228E+05	.338E+05	.364E+06	.173E+05	.466E+06
106.	736.	0.00	0.00	0.00	0.00	.539E+04	.127E+05	.184E+05	.312E+05	.261E+06	.734E+04	.328E+06
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.256E+05	0.00	.256E+05
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.386E+04	.389E+04	.783E+04	.102E+05	.143E+05	.298E+05	.434E+05	.787E+05	.176E+06	.149E+07	.373E+06	.223E+07

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	.138E-03	0.00	0.00	0.00	.321E-03	0.00	0.00	.517E-01	.502E-01
4.73	0.00	0.00	0.00	.596E-03	.399E-02	.514E-02	.601E-02	.123E-02	.234E-02	.734E-03	.186	.290
6.69	0.00	.596E-03	.448E-02	.619E-02	.729E-02	.111E-01	.310E-01	.224E-01	.981E-02	.538E-02	.364	.462
9.45	0.00	.335E-02	.668E-02	.101E-01	.980E-02	.149E-01	.531E-01	.523E-01	.897E-01	.811E-01	.662	.983
13.3	.349E-02	.238E-02	.446E-02	.761E-02	.267E-01	.441E-01	.648E-01	.114	.274	.443	1.43	2.42
18.9	.883E-02	.105E-01	.339E-01	.149E-01	.371E-01	.462E-01	.134	.210	.584	1.88	2.31	5.19
26.6	.161E-01	.254E-01	.353E-01	.251E-01	.938E-01	.197	.214	.326	.935	5.15	3.44	10.5
37.7	.155E-01	.441E-01	.293E-01	.852E-01	.199	.131	.248	.580	1.69	12.4	6.82	19.4
53.2	.234E-01	.113E-01	.160	.826E-01	.185	.414	.362	.648	1.28	17.8	3.14	24.1
75.2	.465E-01	.457E-01	.181	.225	.734E-01	.262	.333	.986	1.78	16.3	.777	20.9
106.	.338E-01	0.00	0.00	0.00	0.00	.241	.567	.465	1.39	11.7	.329	14.7
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00	1.15
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.146	.143	.315	.457	.642	1.31	1.94	3.52	7.88	66.9	16.7	100.

TABLE 12.

Data for the classification and size distribution of free and unliberated PYRITE in the Pb-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	532.	532.
3.35												
0.00	0.00	0.00	6.14	14.3	73.7	84.0	23.6	0.00	0.00	0.00	526.	728.
4.73												
0.00	60.4	222.	245.	175.	73.7	253.	42.0	21.5	0.00	377.	.147E+04	
6.69												
52.2	730.	589.	135.	99.3	63.6	140.	57.4	65.5	0.00	194.	.205E+04	
9.45												
.104E+04	885.	420.	174.	153.	73.7	339.	0.00	229.	101.	311.	.365E+04	
13.3												
.282E+04	.109E+04	286.	0.00	218.	105.	0.00	0.00	0.00	492.	.187E+04	.615E+04	
18.9												
.358E+04	.102E+04	100.	683.	0.00	267.	0.00	0.00	0.00	619.	0.00	.619E+04	
26.6												
.369E+04	345.	166.	263.	0.00	500.	476.	741.	0.00	.258E+04	843.	.969E+04	
37.7												
.255E+04	728.	0.00	0.00	0.00	0.00	.174E+04	0.00	0.00	0.00	0.00	.502E+04	
53.2												
.152E+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.312E+04	0.00	.464E+04	
75.2												
838.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	838.	
106.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
150.												
.152E+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.152E+04	
212.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
.167E+05	.477E+04	.171E+04	.151E+04	719.	.133E+04	.297E+04	841.	316.	.692E+04	.465E+04	.425E+05	

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.25	
3.35												
0.00	0.00	.145E-01	.338E-01	.174	.196	.505E-01	0.00	0.00	0.00	1.24	1.71	
4.73												
0.00	.142	.523	.576	.412	.174	.596	.983E-01	.506E-01	0.00	.867	3.46	
6.69												
.123	1.72	1.28	.318	.234	.164	.330	.135	.154	0.00	.456	4.83	
9.45												
2.45	1.90	.989	.410	.359	.174	.798	0.00	.540	.239	.733	8.59	
13.3												
4.75	2.56	.673	0.00	.514	.436	0.00	0.00	0.00	1.16	1.40	14.5	
18.9												
0.23	2.40	.236	1.61	0.00	.629	0.00	0.00	0.00	1.46	0.00	14.6	
26.6												
0.68	.813	.391	.620	0.00	1.36	1.12	1.75	0.00	6.08	1.98	22.8	
37.7												
6.01	1.71	0.00	0.00	0.00	0.00	4.09	0.00	0.00	0.00	0.00	11.8	
53.2												
3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.35	0.00	10.9	
75.2												
1.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.97	
106.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
150.												
3.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.59	
212.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
39.4	11.2	4.02	3.57	1.69	3.14	6.99	1.98	.745	16.3	11.0	100.0	

TABLE 13.
Data for the classification and size distribution of free and unliberated CHALCOPYRITE in the Zn-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.481E+04	.481E+04
4.73	0.00	0.00	0.00	29.7	55.3	60.4	60.4	29.7	17.4	0.00	.179E+05	.182E+05
6.69	0.00	13.3	68.6	366.	335.	675.	804.	582.	451.	0.00	.348E+05	.382E+05
9.45	7.17	128.	444.	517.	552.	921.	.134E+04	.448E+04	.577E+04	.104E+04	.632E+05	.790E+05
13.3	42.0	169.	320.	584.	655.	.146E+04	.238E+04	.446E+04	.103E+05	.165E+05	.921E+05	.130E+06
18.9	30.7	126.	201.	861.	673.	.191E+04	.252E+04	.667E+04	.212E+05	.546E+05	.131E+06	.220E+06
26.6	99.3	357.	196.	521.	856.	.202E+04	.170E+04	.417E+04	.285E+05	.152E+06	.141E+06	.331E+06
37.7	77.8	171.	400.	0.00	.216E+04	0.00	.243E+04	.800E+04	.171E+05	.234E+06	.114E+06	.378E+06
53.2	0.00	0.00	649.	.154E+04	755.	.335E+04	.210E+04	.250E+04	.282E+05	.222E+06	.866E+05	.347E+06
75.2	0.00	0.00	0.00	0.00	0.00	0.00	.505E+04	.402E+04	.878E+04	.100E+06	.333E+05	.231E+06
106.	0.00	0.00	0.00	0.00	0.00	.389E+04	.520E+04	.598E+04	.469E+04	.620E+05	0.00	.101E+06
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.610E+05	0.00	.610E+05
	257.	985.	.228E+04	.442E+04	.610E+04	.135E+05	.248E+05	.488E+05	.185E+06	.100E+07	.719E+06	.194E+07

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.248	.248
4.73	0.00	0.00	0.00	.153E-02	.285E-02	.417E-02	.311E-02	.158E-02	.897E-03	0.00	.925	.939
6.69	0.00	.686E-03	.354E-02	.188E-01	.284E-01	.348E-01	.425E-01	.308E-01	.232E-01	0.00	1.79	1.97
9.45	.370E-03	.660E-02	.229E-01	.267E-01	.285E-01	.475E-01	.100	.227	.298	.535E-01	3.26	4.07
13.3	.216E-02	.977E-02	.165E-01	.301E-01	.338E-01	.751E-01	.154	.338	.530	.851	4.75	6.60
18.9	.158E-02	.649E-02	.103E-01	.444E-01	.347E-01	.984E-01	.130	.344	1.09	2.82	6.77	11.3
26.6	.512E-02	.184E-01	.101E-01	.269E-01	.441E-01	.104	.878E-01	.215	1.47	7.84	7.25	17.1
37.7	.401E-02	.882E-02	.208E-01	0.00	.111	0.00	.105	.418	.879	10.1	8.88	19.6
53.2	0.00	0.00	.335E-01	.795E-01	.389E-01	.173	.108	.129	1.45	11.4	4.46	17.9
75.2	0.00	0.00	0.00	0.00	0.00	0.00	.260	.287	.453	9.29	1.72	11.9
106.	0.00	0.00	0.00	0.00	0.00	.159	.268	.388	.842	4.23	0.00	5.80
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.15	0.00	3.15
	.133E-01	.508E-01	.117	.228	.314	.696	1.28	2.10	6.44	51.7	37.1	100.0

TABLE 14.

Data for the classification and size distribution of free and unliberated SPHALERITE in the Zn-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	173.	173.
3.35											
0.00	2.05	0.00	8.19	0.00	0.00	0.00	0.00	0.00	0.00	81.9	92.2
4.73											
10.2	0.00	0.00	0.00	9.22	19.5	0.00	0.00	0.00	0.00	255.	294.
6.69											
4.10	0.00	0.00	0.00	0.00	0.00	47.1	0.00	0.00	0.00	99.3	151.
9.45											
2.05	0.00	38.7	55.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	66.1
13.3											
38.9	0.00	0.00	65.5	92.2	167.	0.00	0.00	0.00	0.00	186.	550.
18.9											
13.3	0.00	0.00	0.00	0.00	232.	0.00	371.	0.00	0.00	0.00	617.
26.6											
121.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7+3.	0.00	863.
37.7											
134.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	134.
53.2											
7.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.347E+04	0.00	.347E+04
75.2											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
106.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.											
26.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.6
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
357.	2.05	38.7	129.	101.	419.	47.1	371.	0.00	.421E+04	796.	.646E+04

B.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.68	2.68
3.35											
0.00	.317E-01	0.00	.197	0.00	0.00	0.00	0.00	0.00	0.00	1.27	1.43
4.73											
.159	0.00	0.00	0.00	.143	.301	0.00	0.00	0.00	0.00	3.95	4.55
6.69											
.634E-01	0.00	0.00	0.00	0.00	0.00	.729	0.00	0.00	0.00	1.54	2.33
9.45											
.317E-01	0.00	.476	.836	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.36
13.3											
.682	0.00	0.00	1.01	1.43	2.58	0.00	0.00	0.00	0.00	2.88	8.51
18.9											
.286	0.00	0.00	0.00	0.00	3.60	0.00	5.74	0.00	0.00	0.00	9.54
26.6											
1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.5	0.00	13.4
37.7											
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
53.2											
.111	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.6	0.00	53.7
75.2											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
106.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.											
.412	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.412
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.53	.317E-01	.476	2.00	1.57	6.48	.729	5.74	0.00	65.1	12.3	100.

TABLE 15.

Data for the classification and size distribution of free and unliberated GALENA in the Zn-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	226.	226.
4.73	0.00	4.10	0.00	20.5	6.19	0.00	0.00	0.00	0.00	0.00	253.	286.
6.69	0.00	0.00	57.4	11.3	0.00	18.4	15.4	0.00	0.00	0.00	348.	451.
9.45	0.00	79.9	62.5	44.0	0.00	38.9	56.3	78.7	85.0	74.8	.134E+04	.185E+04
13.3	112.	84.0	67.6	0.00	0.00	0.00	460.	0.00	356.	135.	.126E+04	.247E+04
18.9	172.	168.	56.3	149.	0.00	383.	386.	180.	523.	.167E+04	.189E+04	.558E+04
26.6	92.2	0.00	262.	0.00	337.	0.00	426.	.122E+04	.345E+04	.679E+04	.296E+04	.156E+05
37.7	182.	0.00	0.00	0.00	0.00	0.00	0.00	.153E+04	.156E+04	.666E+04	.157E+04	.115E+05
53.3	352.	245.	0.00	669.	0.00	.216E+04	.136E+04	0.00	.400E+04	.138E+04	.173E+04	.120E+05
75.2	68.6	0.00	937.	.163E+04	0.00	0.00	0.00	.319E+04	0.00	0.00	0.00	.573E+04
106.	296.	.193E+04	0.00	0.00	.248E+04	0.00	0.00	0.00	0.00	.201E+05	0.00	.239E+05
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	165.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	165.
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.144E+04	.168E+04	.146E+04	.252E+04	.874E+04	.262E+04	.278E+04	.618E+04	.997E+04	.368E+05	.116E+05	.797E+05

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.284	.284
4.73	0.00	.514E-02	0.00	.257E-01	.193E-01	0.00	0.00	0.00	0.00	0.00	.316	.359
6.69	0.00	0.00	.726E-01	.141E-01	0.00	.231E-01	.193E-01	0.00	0.00	0.00	.437	.566
9.45	0.00	.106	.784E-01	.553E-01	0.00	.484E-01	.707E-01	.887E-01	.107	.938E-01	1.68	2.32
13.3	.146	.105	.846E-01	0.00	0.00	0.00	.577	0.00	.447	.170	1.56	3.10
18.9	.216	.211	.707E-01	.186	0.00	.481	.485	.226	.657	2.10	2.37	7.01
26.6	.116	0.00	.354	0.00	.423	0.00	.535	1.53	4.33	8.53	3.72	19.5
37.7	.229	0.00	0.00	0.00	0.00	0.00	0.00	1.92	1.96	0.36	1.97	14.4
53.3	.442	.387	0.00	.829	0.00	2.74	1.71	0.00	5.02	1.73	2.25	15.0
75.2	.861E-01	0.00	1.18	2.04	0.00	0.00	0.00	3.89	0.00	0.00	0.00	7.20
106.	.378	1.37	0.00	0.00	3.01	0.00	0.00	0.00	0.00	25.2	0.00	30.0
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	.207	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.207
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.81	2.10	1.84	3.16	3.44	3.29	3.39	7.66	12.5	46.2	14.6	100.

TABLE 16.

Data for the classification and size distribution of free and unliberated PYRITE in the Zn-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	217.	217.
3.35											
0.00	0.00	0.00	0.00	25.0	9.00	0.00	0.00	0.00	0.00	225.	259.
4.73											
0.00	0.00	32.0	35.0	10.00	20.0	0.00	0.00	33.0	0.00	109.	239.
6.69											
0.00	20.0	26.0	43.0	0.00	43.0	87.0	0.00	46.0	0.00	0.00	265.
9.45											
13.0	30.0	52.0	43.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	146.
13.3											
90.0	81.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	179.
18.9											
165.	126.	123.	0.00	177.	275.	0.00	0.00	0.00	0.00	0.00	886.
26.6											
107.	144.	236.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	487.
37.7											
227.	612.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	839.
53.2											
149.	475.	731.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.135E+04
75.2											
653.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	653.
106.											
87.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.0
150.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.144E+04	.158E+04	.128E+04	121.	212.	347.	87.0	0.00	79.8	0.00	551.	.553E+04

B.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.92	3.92
3.35											
0.00	0.00	0.00	0.00	.432	.163	0.00	0.00	0.00	0.00	4.07	4.68
4.73											
0.00	0.00	.578	.633	.181	.362	0.00	0.00	.597	0.00	1.97	4.32
6.69											
0.00	.362	.478	.777	0.00	.777	1.57	0.00	.832	0.00	0.00	4.79
9.45											
.235	.687	.948	.777	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64
13.3											
1.77	1.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.24
18.9											
1.98	2.28	2.22	0.00	3.28	4.97	0.00	0.00	0.00	0.00	0.00	14.6
26.6											
1.93	2.00	4.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.20
37.7											
4.10	11.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.2
53.2											
2.69	8.59	13.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.5
75.2											
11.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.0
106.											
1.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.57
150.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26.0	27.0	21.7	2.19	3.63	6.27	1.57	0.00	1.43	0.00	9.96	100.

TABLE 17.

Data for the classification and size distribution of free and unliberated CHALCOPYRITE in the tailings. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	0.00	10.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	93.0	93.0
3.35												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	167.	167.	
4.73												
0.00	5.00	0.00	0.00	0.00	16.0	0.00	0.00	0.00	0.00	66.0	87.0	
6.69												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	306.	306.	
9.45												
7.00	17.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	496.	520.	
13.3												
37.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	202.	239.	
18.9												
19.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.138E+04	.139E+04	
26.6												
104.	110.	183.	0.00	0.00	0.00	0.00	0.00	0.00	.187E+04	.133E+04	.368E+04	
37.7												
415.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.182E+04	.172E+04	.396E+04	
53.2												
514.	.132E+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.183E+04	
75.2												
382.	.144E+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.182E+04	
106.												
125.	.362E+04	0.00	.112E+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.150E+05	
150.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
212.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	.160E+04	.651E+04	183.	.112E+05	0.00	16.0	0.00	0.00	0.00	.370E+04	.576E+04	.298E+05

B.

	0.00	10.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.342	.342	
3.35												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.576	.576	
4.73												
0.00	.172E-01	0.00	0.00	0.00	.552E-01	0.00	0.00	0.00	0.00	.228	.300	
6.69												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06	1.06	
9.45												
.641E-01	.506E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.71	1.79	
13.3												
.128	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.697	.825	
18.9												
.655E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.75	4.81	
26.6												
.389	.379	.631	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.46	8.00	12.4
37.7												
1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.30	5.92	13.6
53.2												
1.77	4.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.32	
75.2												
1.32	4.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.30	
106.												
.431	12.5	0.00	38.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	51.6	
150.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
212.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	5.53	22.5	.631	38.7	0.00	.552E-01	0.00	0.00	0.00	12.8	19.9	100.0

TABLE 18.

Data for the classification and size distribution of free and unliberated SPHALERITE in the tailings. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

3.35	4.73	6.69	9.45	13.3	18.9	26.6	37.7	53.2	75.2	106.	150.	212.	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	153.			153.
4.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	75.0			83.0
5.00	11.0	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			26.0
17.0	9.00	0.00	32.0	0.00	0.00	0.00	0.00	0.00	0.00	63.0			121.
37.0	36.0	0.00	86.0	0.00	49.0	0.00	0.00	0.00	0.00	0.00			208.
12.0	44.0	0.00	234.	0.00	288.	0.00	0.00	147.	0.00	0.00			637.
97.0	0.00	0.00	0.00	288.	0.00	0.00	0.00	0.00	0.00	0.00			385.
141.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			141.
18.0	211.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			229.
33.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			33.0
373.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			373.
611.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			611.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
.135E+04	315.	0.00	362.	288.	249.	0.00	0.00	147.	0.00	291.			.388E+04

B.

3.35	4.73	6.69	9.45	13.3	18.9	26.6	37.7	53.2	75.2	106.	150.	212.	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.10			5.10
.133	.133	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50			2.77
.167	.367	0.00	.333	0.00	0.00	0.00	0.00	0.00	0.00	0.00			.867
.367	.320	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.00	2.10			4.03
1.23	1.20	0.00	2.87	0.00	1.63	0.00	0.00	0.00	0.00	0.00			6.93
.400	1.47	0.00	7.00	0.00	6.67	0.00	0.00	4.90	0.00	0.00			21.2
3.23	0.00	0.00	0.00	9.60	0.00	0.00	0.00	0.00	0.00	0.00			12.8
4.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			4.70
.600	7.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			7.63
1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			1.10
12.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			12.4
20.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			20.4
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
44.9	10.5	0.00	12.1	9.60	8.30	0.00	0.00	4.90	0.00	9.70			100.

TABLE 19.

Data for the classification and size distribution of free and unliberated GALENA in the tailings. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00	0.00	.302E+04	.302E+04
3.35											
0.00	0.00	6.00	14.0	43.0	25.0	43.0	43.0	16.0	31.0	.814E+04	.838E+04
4.73											
0.00	7.00	50.0	125.	121.	178.	145.	151.	180.	0.00	.162E+05	.172E+05
6.69											
7.00	54.0	118.	148.	186.	178.	647.	553.	967.	257.	.288E+05	.316E+05
9.45											
40.0	160.	148.	173.	468.	465.	.149E+04	.134E+04	.233E+04	.201E+04	.508E+05	.534E+05
13.3											
147.	230.	441.	264.	211.	.109E+04	.108E+04	.204E+04	.400E+04	.100E+05	.858E+05	.105E+06
18.9											
66.0	393.	409.	384.	619.	769.	880.	.320E+04	.899E+04	.267E+05	.144E+06	.187E+06
26.6											
525.	522.	.108E+04	797.	359.	613.	.200E+04	.444E+04	.113E+05	.593E+05	.201E+06	.282E+06
37.7											
.182E+04	438.	0.00	.264E+04	.173E+04	0.00	.658E+04	.389E+04	.112E+05	.155E+06	.279E+06	.461E+06
53.2											
.119E+04	.133E+04	849.	.168E+04	0.00	.239E+04	.218E+04	.864E+04	.170E+05	.276E+06	.273E+06	.583E+06
75.2											
.254E+04	.122E+04	.373E+04	.251E+04	.321E+04	.618E+04	0.00	.670E+04	.123E+05	.298E+06	.811E+06	.540E+06
106.											
.182E+04	.215E+04	0.00	.747E+04	0.00	0.00	.171E+05	.112E+05	.163E+05	.309E+06	.507E+05	.416E+06
150.											
920.	0.00	0.00	0.00	0.00	0.00	0.00	.277E+05	0.00	.386E+05	0.00	.672E+05
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.827E+04	.650E+04	.683E+04	.162E+05	.698E+04	.119E+05	.321E+05	.691E+05	.846E+05	.116E+07	.135E+07	.277E+07

B.

9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.325E-03	0.00	.109	.109
3.35											
0.00	0.00	.217E-03	.506E-03	.177E-02	.903E-03	.177E-02	.155E-02	.570E-03	.112E-02	.294	.303
4.73											
0.00	.253E-03	.181E-02	.452E-02	.437E-02	.643E-02	.524E-02	.545E-02	.650E-02	0.00	.586	.621
6.69											
.253E-03	.195E-02	.426E-02	.535E-02	.383E-02	.643E-02	.234E-01	.193E-01	.349E-01	.928E-02	1.04	1.15
9.45											
.144E-02	.578E-02	.535E-02	.625E-02	.176E-01	.168E-01	.538E-01	.405E-01	.843E-01	.726E-01	1.03	2.15
13.3											
.531E-02	.831E-02	.159E-01	.954E-02	.762E-02	.392E-01	.389E-01	.736E-01	.145	.362	3.10	3.80
18.9											
.238E-02	.142E-01	.148E-01	.139E-01	.224E-01	.278E-01	.318E-01	.116	.325	.965	5.21	6.74
26.6											
.190E-01	.183E-01	.389E-01	.288E-01	.138E-01	.221E-01	.722E-01	.100	.400	2.14	7.25	10.2
37.7											
.368E-01	.158E-01	0.00	.955E-01	.626E-01	0.00	.238	.112	.406	5.62	10.1	16.6
53.2											
.428E-01	.408E-01	.307E-01	.605E-01	0.00	.863E-01	.789E-01	.312	.613	9.95	9.85	21.1
75.2											
.918E-01	.439E-01	.135	.980E-01	.116	.823	0.00	.242	.445	10.0	7.62	19.0
106.											
.658E-01	.778E-01	0.00	.270	0.00	0.00	.616	.406	.598	11.2	1.83	15.0
150.											
.332E-01	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.39	0.00	2.43
212.											
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.299	.235	.247	.585	.249	.429	1.16	2.58	3.06	42.5	48.8	100.

TABLE 20.

Data for the classification and size distribution of free and unliberated PYRITE in the tailings. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

Appendix C

RAW MINERAL ASSOCIATION DATA

TABLE 1

MINERAL ASSOCIATIONS OF CHALCOPYRITE IN THE FIVE CHISEL LAKE END PRODUCTS.
DATA PRESENTED AS SURFACE AREA (um^2).

PARTICLE TYPE	Feed.	Cu-Conc.	Pb-Conc.	Zn-Conc.	Tailings
FREE	18200.	196000.	1640.	4660.	551.
BINARY					
Cpy + Py	502.	11550.	72.	0.	30.
Cpy + Gan	2790.	109000.	283.	2220.	73.
Cpy + Sph	6630.	18500.	1160.	13200.	7.
Cpy + Gal	0.	3230.	845.	0.	0.
TERNARY					
Cpy + Py + Other	4740.	108000.	13700.	4730.	1890.
Cpy + Gan + Other	5060.	302000.	4930.	18000.	3400.
Cpy + Sph + Other	5720.	117000.	15100.	14000.	558.
Cpy + Gal + Other	307.	20800.	12700.	1560.	367.
Cpy + All Other	11600.	432000.	20800.	22400.	4870.

TABLE 2

ADJUSTED MINERAL ASSOCIATIONS OF CHALCOPYRITE
IN THE FIVE CHISEL LAKE END PRODUCTS.

DATA PRESENTED AS MODAL FRACTIONS OF THE ADJUSTED Cu ASSAY.

PRODUCT	ADJUSTED Cu Assay	Free Cpy	Cpy+Py	Cpy+Gan	Cpy+Sph	Cpy+Gal	Ternary Cpy
Feed	0.35	0.07	0.004	0.03	0.05	0.001	0.21
Cu-Conc.	19.1	6.35	0.310	2.32	0.46	0.058	9.89
Pb-Conc.	0.28	0.02	0.001	0.00	0.01	0.009	0.23
Zn-Conc.	0.51	0.06	0.001	0.03	0.16	0.001	0.25
Tails.	0.07	0.01	0.001	0.00	0.00	0.001	0.06

TABLE 3

MINERAL ASSOCIATIONS OF SPHALERITE IN THE FIVE CHISEL LAKE END PRODUCTS.

DATA IN SURFACE AREA (um^2).

PARTICLE TYPE	Feed.	Cu-Conc.	Pb-Conc.	Zn-Conc.	Tailings
FREE	717000.	72300.	65500.	719000.	5760.
BINARY					
Sph + Py	11700.	154.	3600.	1340.	1820.
Sph + Gan	277000.	35600.	3510.	427000.	1910.
Sph + Cpy	83900.	84700.	5420.	286000.	1070.
Sph + Gal	15500.	1460.	32500.	1920.	0.
TERNARY					
Sph + Py + Other	88200.	12700.	81700.	114000.	18300.
Sph + Gan + Other	159000.	102000.	156000.	478000.	14100.
Sph + Cpy + Other	111000.	117000.	172000.	461000.	5040.
Sph + Gal + Other	36100.	9310.	279000.	42000.	508.
Sph + All Other	184000.	121000.	436000.	506000.	18400.

TABLE 4

ADJUSTED MINERAL ASSOCIATIONS OF SPHALERITE IN THE FIVE CHISEL LAKE END PRODUCTS.

DATA PRESENTED AS MODAL FRACTIONS OF THE ADJUSTED Zn ASSAY.

PRODUCT	ADJUSTED Zn Assay	Free Sph	Sph+Py	Sph+Gan	Sph+Cpy	Sph+Gal	Ternary Sph
Feed	16.7	8.14	0.05	3.39	1.48	0.03	3.37
Cu-Conc.	13.9	3.20	0.01	1.57	3.74	0.06	5.32
Pb-Conc.	10.4	1.25	0.07	0.07	0.10	0.65	8.30
Zn-Conc.	53.9	27.1	0.03	11.3	4.84	0.04	9.62
Tails.	0.78	0.16	0.06	0.05	0.03	0.00	0.50

TABLE 5

MINERAL ASSOCIATIONS OF GALENA IN THE FIVE CHISEL LAKE END PRODUCTS.

DATA PRESENTED AS SURFACE AREA (um^2).

PARTICLE TYPE	Feed.	Cu-Conc.	Pb-Conc.	Zn-Conc.	Tailings
FREE	14100.	9490.	699000.	946.	537.
BINARY					
GAL + Py	618.	21.	16000.	0.	24.
Gal + Gan	2820.	1730.	90700.	4420.	156.
Gal + Sph	1620.	548.	10600.	50.	0.
Gal + Cpy	0.	354.	2930.	0.	0.
TERNARY					
Gal + Py + Other	1380.	2220.	82200.	60.	1190.
Gal + Gan + Other	3530.	9150.	140000.	542.	1900.
Gal + Sph + Other	1790.	2650.	99500.	1160.	267.
Gal + Cpy + Other	80.	5360.	46600.	48.	280.
Gal + All Other	4070.	10100.	290000.	1200.	2530.

TABLE 6

ADJUSTED MINERAL ASSOCIATIONS OF GALENA
IN THE FIVE CHISEL LAKE END PRODUCTS.

DATA PRESENTED AS MODAL FRACTIONS OF THE ADJUSTED Pb ASSAY.

PRODUCT	ADJUSTED Pb Assay	Free Gal	Gal+Py	Gal+Gan	Gal+Sph	Gal+Cpy	Ternary Gal
Feed	0.71	0.370	0.010	0.105	0.007	0.002	0.216
Cu-Conc.	2.60	1.081	0.002	0.203	0.065	0.041	1.170
Pb-Conc.	27.0	18.42	0.463	2.107	0.281	0.061	6.162
Zn-Conc.	0.32	0.039	0.001	0.199	0.002	0.001	0.057
Tails.	0.14	0.014	0.001	0.007	0.001	0.001	0.107

Appendix D

RAW SIEVE SIZE AND PARTICLE SIZE DATA

TABLE 1

SIEVE SIZE ANALYSES FOR THE FIVE CHISEL STALL LAKE END PRODUCTS.

(Retained Weight)

SAMPLE.	Mesh Numbers (and Screen Opening Sizes)						
	+48 (295um)	+65 (208um)	+100 (147um)	+150 (104um)	+200 (74um)	+325 (43um)	-325
1. Feed	2.04	3.08	6.84	10.8	11.9	16.9	48.5
2. Cu-Conc.	0.10	0.31	0.68	2.11	6.85	15.9	74.1
3. Pb-Conc.	0.08	0.46	2.80	8.87	16.0	27.1	44.7
4. Zn-Conc.	0.69	1.80	5.07	9.56	12.7	19.9	50.2
5. Tailings	3.08	4.64	8.16	11.9	15.0	16.3	40.9

TABLE 2

HOST PARTICLE SIZE DISTRIBUTIONS OF CHALCOPYRITE IN THE FIVE CHISEL LAKE END PRODUCTS.

HOST PARTICLE DIAMETER (um)	Frequency (%)				
	Feed	Cu-Conc.	Pb-Conc.	Zn-Conc.	Tailings
-3.4	0.13	0.14	1.14	1.25	3.92
-4.7	1.19	0.44	2.05	1.71	4.68
-6.7	2.76	0.91	2.72	3.46	4.32
-9.5	5.08	1.73	3.67	4.83	4.79
-13.	8.32	2.81	4.83	8.59	2.64
-19.	16.9	5.92	7.46	14.5	3.24
-27.	20.2	11.5	10.6	14.6	14.6
-38.	28.2	16.3	9.93	22.8	8.80
-53.	13.3	23.0	12.6	11.8	15.2
-75.	2.34	27.5	41.5	10.9	24.5
-106.	1.50	9.74	1.50	1.97	11.8
-150.	0.03	0.00	1.95	0.00	1.57
+150.	0.03	0.00	0.00	3.59	0.00

TABLE 3

HOST PARTICLE SIZE DISTRIBUTIONS OF SPHALERITE IN THE FIVE CHISEL LAKE END PRODUCTS.

HOST PARTICLE DIAMETER (um)	Frequency (%)				
	Feed	Cu-Conc.	Pb-Conc.	Zn-Conc.	Tailings
-3.4	0.03	0.14	0.26	0.25	0.34
-4.7	0.66	0.49	0.72	0.94	0.58
-6.7	1.47	0.99	1.09	1.97	0.30
-9.5	3.21	1.86	1.57	4.07	1.06
-13.	5.31	3.89	2.95	6.68	1.79
-19.	9.01	7.24	5.81	11.3	0.83
-27.	14.7	16.3	8.91	17.1	4.81
-38.	18.7	18.5	17.2	19.5	12.4
-53.	21.0	30.3	21.7	17.9	13.6
-75.	17.0	17.9	18.9	11.9	6.32
-106.	5.64	2.37	15.8	5.20	6.30
-150.	2.10	0.00	5.06	0.00	51.6
+150.	1.12	0.00	0.00	3.15	0.00

TABLE 4

HOST PARTICLE SIZE DISTRIBUTIONS OF GALENA IN THE FIVE CHISEL LAKE END PRODUCTS.

HOST PARTICLE DIAMETER (um)	Frequency (%)				
	Feed	Cu-Conc.	Pb-Conc.	Zn-Conc.	Tailings
-3.4	2.17	2.45	1.68	2.68	5.10
-4.7	4.23	3.49	2.30	1.43	2.77
-6.7	6.85	5.05	3.25	4.55	0.87
-9.5	10.8	5.17	4.30	2.33	4.03
-13.	12.2	8.34	6.16	1.36	6.93
-19.	21.3	14.2	8.93	8.51	21.2
-27.	19.1	16.8	11.3	9.54	12.8
-38.	8.46	22.7	14.8	13.4	4.70
-53.	11.3	5.37	16.3	2.08	7.63
-75.	2.10	15.9	13.8	53.7	1.10
-106.	0.93	0.49	10.3	0.00	12.4
-150.	0.54	0.00	3.04	0.00	20.4
+150.	0.04	0.00	3.80	0.42	0.00

TABLE 5

HOST PARTICLE SIZE DISTRIBUTIONS OF PYRITE IN THE FIVE CHISEL LAKE END PRODUCTS.

HOST PARTICLE DIAMETER (um)	Frequency (%)				
	Feed	Cu-Conc.	Pb-Conc.	Zn-Conc.	Tailings
-3.4	0.02	0.12	0.05	0.28	0.11
-4.7	0.45	0.34	0.20	0.36	0.30
-6.7	1.13	0.64	0.46	0.57	0.62
-9.5	2.15	1.54	0.98	2.32	1.15
-13.	4.20	2.61	2.42	3.10	2.15
-19.	7.13	5.56	5.19	7.01	3.80
-27.	12.4	13.0	10.5	19.5	6.74
-38.	17.9	30.6	19.4	14.4	10.2
-53.	22.0	28.0	24.1	15.0	16.6
-75.	20.1	13.5	20.9	7.20	21.1
-106.	11.0	4.10	14.7	30.0	19.8
-150.	1.49	0.00	1.15	0.00	15.0
+150.	0.07	0.00	0.00	0.21	2.43

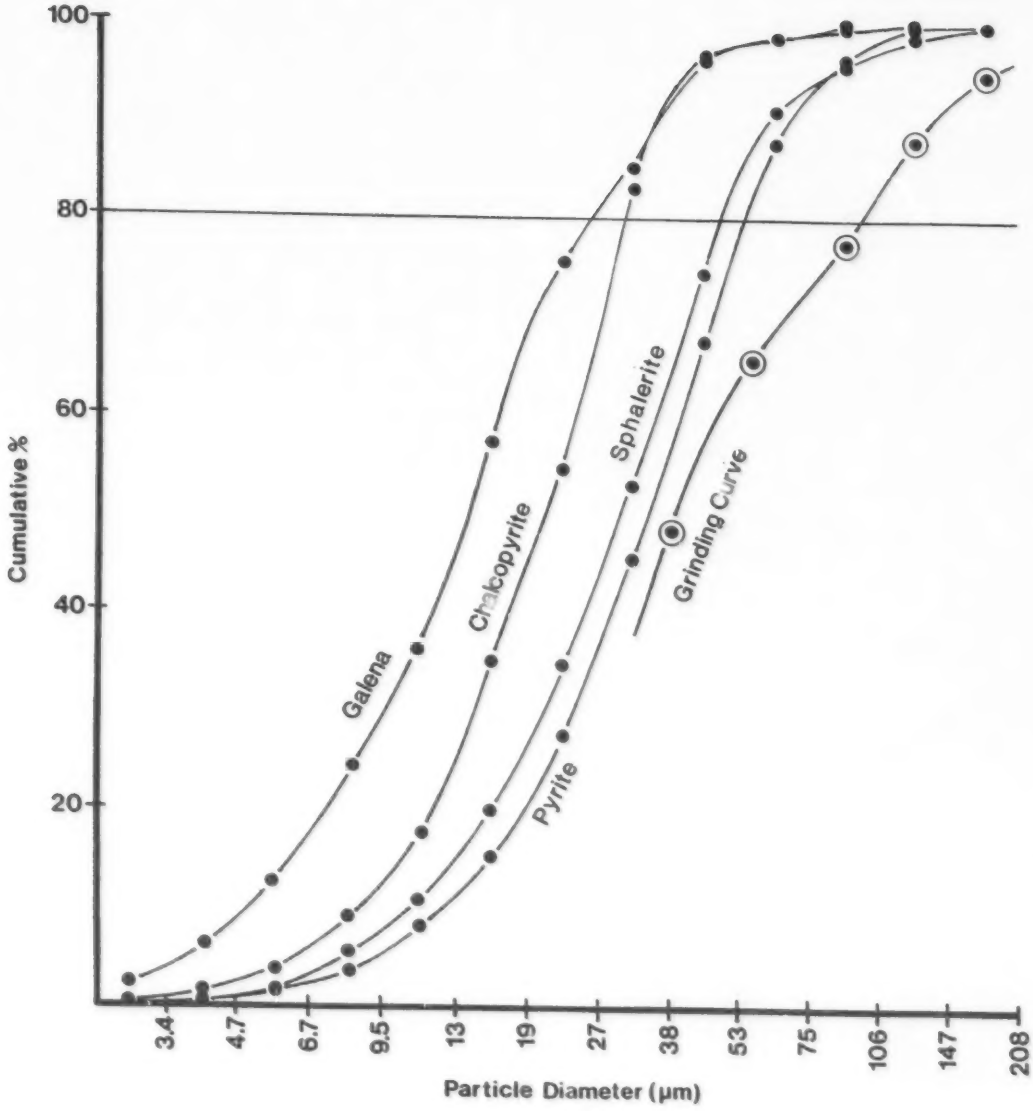

FIGURE 1.
THE HOST PARTICLE SIZE DISTRIBUTIONS OF CHALCOPYRITE, SPHALERITE, GALENA AND PYRITE, AND THE GRINDING CURVE IN THE CHISEL LAKE FLOTATION FEED.